STRATHFIELD MUNICIPAL COUNCIL

COOKS RIVER & COXS CREEK FLOOD STUDY

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COOKS RIVER AND COXS CREEK FLOOD STUDY

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FOREWORD

The NSW State Government's Flood Prone Land Policy provides a framework to ensure the sustainable use of floodplain environments. The primary objective of the Policy is to reduce the impact of flooding and flood liability on floodplain users and to reduce private and public losses from floods, utilising ecologically positive methods wherever possible. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State Government provides funding for flood studies, floodplain risk management plans and works to alleviate existing flood problems, to undertake the necessary technical studies to identify and address the problem and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Federal Government may also provide funding in some circumstances.

In order to implement the Policy within its local government area (LGA), Strathfield Municipal Council has embarked on a program of studies and actions as set out in the NSW Floodplain Development Manual under the guidance of the Department of Environment, Climate Change and Water (DECCW) and with the assistance of other agencies including the Department of Planning, the State Emergency Services and Sydney Water.

The Policy provides for technical and financial support by the Government through four sequential stages:

1. Flood Study
- Determine the nature and extent of the flood problem for the full range of flood events up to the Probable Maximum Flood (PMF).

2. Floodplain Risk Management
- Evaluates management options for the floodplain in respect of both existing and proposed development taking into consideration social, ecological and environmental factors related to flood risk.

3. Floodplain Risk Management Plan
- Involves formal adoption by Council of a plan of management for the floodplain after consultation with the public.

4. Implementation of the Plan
- Involves construction of flood mitigation works to protect existing development, implementation of community awareness programs to heighten flood awareness, improved evacuation arrangements to minimise flood damages and the risk to life, and the introduction of development control policies at various levels within the planning framework to ensure new development is constructed in a manner compatible with the flood hazard.

The Cooks River and Coxs Creek Flood Study constitutes the first stage of the management process for the areas adjacent to the Cooks River and Coxs Creek (the suburbs of Strathfield South, Enfield, Enfield South, Rookwood, Chullora, Potts Hill, Bankstown North, Greenacre, Punchbowl, Mt Lewis, Wiley Park, Roselands and Belmore) and has been prepared for Strathfield Municipal Council by WMAwater under the guidance of Council's floodplain management committee. It provides the basis for the future management of flood liable lands along the Cooks River and Coxs Creek within the Strathfield Municipal Council local government area.

This study considers both inundation from the Cooks River and Coxs Creek (mainstream flooding) as well as inundation within the overland flow areas drained by a piped drainage system (overland flow flooding). The possible effects of a climate change induced increase in design rainfall intensities were also analysed.

EXECUTIVE SUMMARY

The NSW Government's Flood Policy provides for:

- *a framework to ensure the sustainable use of floodplain environments,*
- *solutions to flooding problems,*
- *a means of ensuring new development is compatible with the flood hazard.*

Implementation of the Policy requires a four stage approach, the first of which is preparation of a Flood Study to determine the nature and extent of the flood problem.

The Cooks River and Coxs Creek Flood Study was initiated as a result of flooding of roads and residential areas, most recently in August 1986, February 1990 and March 1991. This report has been prepared by WMAwater for Strathfield Municipal Council and the Department of Environment, Climate Change and Water (DECCW) under the guidance of Council's floodplain management committee. A Draft of this Flood Study was placed on public exhibition in June 2010 but no significant feedback was obtained from the public.

The specific aims of the Cooks River and Coxs Creek Flood Study are to:

- *define flood behavior in terms of flood levels, depths, velocities, flows and extents within the Cooks River and Coxs Creek catchment study area,*
- *prepare flood hazard and flood extent mapping,*
- *prepare suitable models of the catchment and floodplain for use in a subsequent Floodplain Risk Management Study.*
- *to assess the adequacy and capacity of Council's existing pipe network and quantify overland flows,*
- *to consider the potential effects of a climate change induced increase in design rainfall intensities.*

Description of Creek System (Section 2 of report): The study area lies on both sides of the Cooks River and Coxs Creek within the Strathfield Municipal Council Local Government Area (LGA). Runoff from the Bankstown and Canterbury LGA enters the study area to the west of Roberts Road and south of Juno Parade. Both the Cooks River and the Coxs Creek channels are concrete lined except where the Cooks River enters Strathfield Golf Course. Upstream of the golf course the river reduces to become a small semi natural channel. Upstream of the Enfield Marshalling Yards Coxs Creek continues as an open concrete lined channel for a few kilometers. The majority of the study area is residential developments comprising detached homes which are drained by Council's stormwater drainage system.

The land usage within the study area comprises of a mix of residential, industrial and commercial developments together with significant amounts of open space (parks, Strathfield Golf Course, Freshwater Park) and the Enfield Marshalling Yards at Strathfield South/Greenacre.

Past Flooding Problems (Sections 2 and 3 of report): A number of past reports have been prepared for Council to identify, quantify and manage existing flood problem areas (High Street, Augusta Street and others). As a result Council has undertaken works to reduce the problem. Council has also introduced development controls to ensure that adequate studies are undertaken to ensure new development are constructed in a manner compatible with the flood risk and will not exacerbate an existing flood problem.

Available Data (Section 3 of report): The Cooks River Flood Study was completed in February 2009 (Report prepared for Sydney Water) and provides design flood levels along the Cooks River to Centenary Drive and Coxs Creek to downstream of the Enfield Marshalling Yards.

Airborne Laser Scanning (ALS) survey (provides a very accurate and detailed definition of the ground surface) was available for the entire study area and was used to determine catchment areas as well as to define the topography for the hydraulic models. Council provided details on the pit and pipe network within Strathfield and the adjoining Bankstown Council parts of the study area.

Previous reports were available to describe historical flooding in the catchment and further data was obtained as part of the present study through distribution of a Newsletter and Questionnaire. Historical rainfall was also collected.

Approach (Section 4 of report) : A DRAINS hydrologic model (converts rainfall to runoff) was established for the study area to provide inflow hydrographs to the TUFLOW 2D hydraulic model which was used to determine design flood levels, depths, velocities and extents.

Calibration to Historical Flood Levels (Section 6.4 of report): Due to the lack of available data a rigorous calibration (matching of actual flood height data to that produced from the models and so verifying their accuracy) of the TUFLOW model could not be undertaken. This situation is typical of all urban catchments where there are limited flood records available (no instruments measuring water level and as the flood happens very quickly residents may not actually see the floodwaters – thus reliance has to be made on debris marks or such. Questionnaires were sent out as part of this study to allow residents to advise of past flood events and data). However a limited calibration was undertaken based on recorded flood levels. This generally indicates that the results from TUFLOW are similar to historical data. However immediately following the next major flood both rainfall and flood level data should be collected and used to further verify the results.

Determination of Design Flood Flows and Levels (Section 7 of report): Design rainfall data from Strathfield Council and design rainfall patterns from Australian Rainfall and Runoff were obtained and input to the modeling procedure to obtain the design flood data. Flooding is a combination of runoff from the study area catchment as well as from high levels in the Cooks River and Coxs Creek. Detailed mapping was undertaken for the full range of design events (2, 5, 10, 20, 100 and 200 year ARI design storms and the Probable Maximum Flood) with the results provided as maps showing:

- Cooks River and Coxs Creek flooding taken from the Sydney Water Cooks River Flood

Study of 2009 (Figures 11a to d),
- Flood contours, extents and depths from the study area (Figures 13a to g),
- Flood profiles (Figures 14a to 14d),
- Hazard and hydraulic classification (Figures 15a to 15g).

Accuracy of Design Flood Levels and Extents (Sections 7.3 and 7.4): Sensitivity analyses (to assess the effects of changing various model parameters) were undertaken of both the DRAINS and TUFLOW model results. Part of this analysis was to assess the effects of possible increases in design rainfall (10%, 20% and 30%) due to climate change. The results indicate that the average increase (based on a comparison of the peak level at the inlet pits) in the 100 year ARI event is:

- low level rainfall increase of 10% = +0.03m,
- medium level rainfall increase of 20% = +0.05m,
- high level rainfall increase of 30% = +0.06m.

However the results do show a significant variation between locations.

Due to the limited quantity and quality of the calibration data available and in view of the sensitivity analyses, it is estimated that the order of accuracy of the design flood levels is up to ±0.5m, however in many places the order of accuracy will be ±0.3m. The accuracy of the flood extent largely depends on the slope of the land and may vary from of the order of 1m to 10m. These orders of accuracy are typical of such studies and can only be improved upon with additional observed flood data to refine the model calibration and more detailed and accurate definition of the terrain.

The following table provides an indication of the number of properties that are inundated in the various design events and whether the inundation is due to overland, mainstream or a combination of both types of flooding (*note: a property is taken as inundated for this table if any part of the property is inundated however small or shallow the depth of inundation*).

	Average Recurrence Interval						
Mode of Flood Affectation	2 year	5 year	10 year	20 year	100 year	200 year	**PMF**
Overland Flooding	2261	<u>2469</u>	<u>2527</u>	2355	2342	<u>2642</u>	2283
Mainstream Flooding	181	n/a	n/a	309	452	n/a	938
Overland AND Mainstream	94	n/a	n/a	205	280	n/a	842

Notes: 1. n/a data for mainstream flooding not available, thus the values for overland flooding (underlined) are conservative
2. the values for overland flooding decrease from the 10 year ARI to the PMF as the properties in the lower part of the floodplain become included within the mainstream flooding extent.

Outcomes: The main outcomes of this study are:

- full documentation of the methodology and results,
- preparation of flood contour, depth, velocity, hazard and extent maps for the study area,
- a modeling platform that will form the basis for a subsequent Floodplain Risk Management Study and Plan.

Recommendations: This Flood Study should be adopted by Council before proceeding with the subsequent floodplain risk management Study and Plan. As part of these subsequent studies a risk analysis of the implications of climate change on flooding should be undertaken

The key recommendation from this study is to highlight the importance of collecting and maintaining a database of historical rainfall and flood height data. It is vital that information from future flood events is collected within 24 hours and the magnitude and direction of flow paths through private property recorded. This information will significantly improve the accuracy of the design flood levels and extents and ensure that known flood areas are identified and assessed. Data collection can be undertaken by Council Officers digitally photographing flood marks etc (they can be leveled later based on the photograph) and possibly mailing out a resident questionnaire requesting information and photographs. Unfortunately if this process is not done quickly, information is lost forever.

1. INTRODUCTION

1.1. General

The study area (Figures 1 and 2) includes the Cooks River and Coxs Creek catchments to the crossing of the Cooks River with Punchbowl Road within the Strathfield Municipal Council LGA. The catchment drains the suburbs of Strathfield South, Enfield, Enfield South, Rookwood, Chullora, Potts Hill, Bankstown North, Greenacre, Punchbowl, Mt Lewis, Wiley Park, Roselands and Belmore. Runoff from the Bankstown LGA enters the study area to the west of Roberts Road. To the south and east lie the Canterbury and Burwood Council LGAs.

Flooding problems have been experienced at a number of locations within the catchment during periods of heavy rainfall. Strathfield Municipal Council has undertaken to address this issue by preparing a Flood Study within the section of the LGA affected by the Cooks River and Coxs Creek catchment. The study area comprises the pipe and overland flow systems as well as the open channels of the Cooks River and Coxs Creek.

The drainage system within the catchment comprises a network of underground pipes and box culverts that were largely installed by Strathfield Municipal Council over 50 years ago. The open channel section and larger pipe systems were installed by Sydney Water during the 1930's depression.

The land usage within the study area comprises of a mix of residential, industrial and commercial developments together with significant amounts of open space (parks, Strathfield Golf Course, Freshwater Park) and the Enfield Marshalling Yards at Strathfield South/Greenacre. Figure 3 provides a map of the assumed percentage of imperviousness of the catchment. This information was used in the hydrologic model to determine the amount of catchment runoff. Figure 4 provides details of reports on past flood events.

1.2. Objectives

Strathfield Municipal Council engaged WMAwater to undertake the Cooks River and Coxs Creek Flood Study utilising current technology and data. The information and results obtained from the study will provide a firm basis for the development of targeted stormwater management studies, and a subsequent Floodplain Risk Management Study and Plan.

The study was developed in order to meet the primary objective of defining the flood behaviour (2, 5, 10, 20, 100 and 200 year ARI design storms and the Probable Maximum Flood) in the Cooks River and Coxs Creek catchment and to:

- define flood behavior in terms of flood levels, depths, velocities, flows and flood extents within the Cooks River and Coxs Creek catchment study area,
- prepare flood hazard and flood extent mapping,
- prepare suitable models of the catchment and floodplain for use in a subsequent Floodplain Risk Management Study.
- to assess the adequacy and capacity of Council's existing pipe network and quantify

overland flows,

- to consider the potential effects of a climate change induced increase in design rainfall intensities.

This report details the results and findings of the Flood Study investigations. The key elements include:

- description of study area,
- results of distribution of questionnaires (Figure 5),
- a summary of available historical flood related data,
- calibration of the hydrologic and hydraulic models,
- definition of the design flood behaviour for existing conditions through the analysis and interpretation of model results
- sensitivity analysis and the assessment of the effects of a climate change induced increase in design rainfall intensities.

A glossary of flood related terms is provided in Appendix A.

2. BACKGROUND

2.1. Study Area

The study area comprises the 22.2 km^2 catchment which ultimately drains into the Cooks River at its crossing with Punchbowl Road/Coronation Parade within the Strathfield LGA. The study area is heavily developed and consists primarily of residential and industrial developments, although there are some minor commercial and medium density home units adjacent to Liverpool Road. There is one public school, two private schools, the Australian Catholic University, several parks and recreation reserves as well as Strathfield Golf Course and Freshwater Park. Approximately 1.0 km^2 is occupied by the Enfield Marshalling Yards.

To the south of Liverpool Road (Hume Highway) the study area is bounded by Roberts Road, Juno Parade, Punchbowl Road and Coronation Parade that define the boundary of the Strathfield LGA. To the north of Liverpool Road (Hume Highway) the study area is defined by the ill defined catchment boundary between the Parramatta River to the north and the Cooks River to the south.

In terms of local drainage, the roads have been formed with kerbs and gutters draining to an underground pipe system which discharges to the open channel system. The open channel system consists of the Cooks River and Coxs Creek.

The Coxs Creek channel is lined within the entire study area. However it is contained within a box culvert through the Enfield Marshalling Yards and continues on the upstream side as an open channel. The Cooks River is lined within the study area except upstream of Hedges Avenue within Freshwater Park and Strathfield Golf course where it is in a semi natural condition. As part of recent works in this area it is part vegetated and part rock lined. This vegetation is “maintained” by the golf course.

A detailed description of key locations (Figure 6) within the study area is provided in Appendix B. Figure 7 provides an indication of the relief of the study area.

2.2. Causes of Flooding

Based on the available information, observations from the site and experience in similar catchments, flooding within the study area occurs as a result of two main mechanisms:

- due to flow in excess of the capacity of the pit and pipe networks (Figure 8) being conveyed along roads and overland flowpaths to natural low points, ultimately this flow reaches the open channels of the Cooks River and Coxs Creek (termed **Overland** flooding in this report). Flooding may be exacerbated by inadequate or blocked local drainage systems and restrictions in overland flow paths such as buildings or fences,
- due to the Cooks River and Coxs Creek overtopping the main channel (Figure 9) and spreading into the overbank areas (termed **Mainstream** flooding in this report).

Flooding due to overtopping of the main channels of Cooks River and Coxs Creek has been investigated in a 2009 Sydney Water Cooks River Flood Study (Reference 1) and key results are included on Figure 9. The focus of the present study is flooding due to the former mechanism of flow in excess of the pit and pipe drainage system.

2.3. Pit and Pipe Network

Strathfield Municipal Council provided a database of the pit and pipe network within the study area. This database was amended to exclude minor pit/pipe systems and is shown on Figure 8. The database was not verified as part of this study unless obvious errors were discovered. Table 1 provides a summary of this piped network system.

Table 1: Pit and Pipe Network

Pit Type	Number
Kerb inlet only	12
Grate inlet only	130
Grate and Kerb inlet	800
Junction or bend or inspection - No inlet	256
Outlet	48
Total	**1246**

Pipe Diameter *	Number	Length (m)
< 450 mm	644	20920
450 - 525 mm	154	2830
525 - 600mm	61	2770
600 - 750 mm	92	2610
750 - 900 mm	43	1830
900 - 1050 mm	43	1100
> 1050 mm	46	2310
Box culverts	128	4910
Total	**1211**	**39280**

2.4. Previous Studies

2.4.1. Stormwater Master Plan for High Street Drainage Catchment at South Strathfield NSW, June 1983 (Reference 2)

This report was prepared by K.R. Stubbs & Associates Pty Ltd for Strathfield Municipal Council and investigates the behaviour of drainage in the High Street catchment. The report also includes preparation of a stormwater master plan.

The study provides details on gutters, gully pits, crown heights, kerb heights, underground pipes, sag points and smaller open channels throughout the catchment.

The report generally notes that re-development is underway and that flows are increasing due to increasing impervious areas. Flooding in Wallis Avenue was found to be largely dependant on the downstream tailwater level in the Cooks River. The Cooks River water level was determined to have an influence on all local catchment flood levels downstream of Homebush Road. High Street and Wallis Avenue were found to be the most impacted by flooding.

2.4.2. Augusta Street Catchment Study, Stage 1 Report, Volume 1, Main Report, October 1991 (Reference 3)

This report was prepared for Strathfield Municipal Council by Bewsher Consulting and examines the main trunk drainage system within the Augusta Street catchment from Homebush Road to the Cooks River.

Questionnaires were sent to residents, of which 41 of 85 were returned and 70% of the respondents had some form of flood problem. Three properties were found to have flooding above floor level in severe storms. The questionnaires identified a major flood event in Augusta Street on 5th August 1986. The damages from this storm were estimated to be $25,000 in direct costs to residents. Other major events included 11th March 1991 and the first week of February 1990. There was little consistency throughout the catchment regarding the date of the worst flood event.

A survey of ground levels along the trunk system through Augusta Street was used in the study.

Design flows were simulated by modifying an ILSAX model prepared by Council and adjusted using hydraulic grade line analysis to improve the assessment of pipe hydraulics. The trunk system was found to have approximately one half of the capacity required for a 1 year ARI flood event. The rest of the stormwater system had about a 1 year ARI capacity, excluding the new drainage in Chalmers Road which was estimated to have a capacity for a 5 to 10 year ARI event. Trunk pipelines downstream of Chalmers Road and Wallis Avenue were found to have reduced effective capacities due to limited inlet capacity.

Various recommendations were made to improve the capacity of the stormwater system and various options were tested in ILSAX, including the construction of detention basins in Strathfield Park.

2.4.3. Augusta Street Catchment Feasibility Design Report for Strathfield Park Basins, October 1992 (Reference 4)

This report was prepared by Bewsher Pty Ltd to assess the feasibility and construction aspects of the Strathfield Park basins as proposed in the Augusta Street Catchment Study (Reference 3). A detailed survey of Strathfield Park was undertaken, a number of test pits were dug and services were examined.

Previous results from Reference 3 were found to be inaccurate due to incorrect pit information and a revised ILSAX model indicated that storage in the upper basin of the park was not sufficient; with spilling occurring in all design events. Very little attenuation of the flood peak was found to be achieved.

However, the lower basin was found to achieve a higher level of attenuation. A dual basin solution was recommended and removing relatively impermeable sub-soil in Strathfield Park was considered and costed.

2.4.4. High Street Catchment Study, July 1994 (Reference 5)

Strathfield Municipal Council commissioned Bewsher Consulting to conduct a study of the High Street catchment to examine flooding issues within the catchment and suggest mitigation works.

A total of 112 questionnaires were sent to residents with 30% returned, 20% of respondents had minor flooding issues and 40% had major flooding issues. Two properties mentioned inundation above the floor level. Properties on the southern side of Long Street returned the most questionnaires and appear to have the most flood related complaints. No. 27 Long Street appeared to be particularly affected with water entering the property from Cross Street to the east. Some residents reported that ponding to a high depth occurred at the High Street and Wallis Avenue intersection.

Residents recall August 1986 as being the worst flood event but also mentioned March 1991 and February 1990. Flood photos are available for March 1991. The August 1986 event was estimated as being a 20 year ARI event. In many cases, flow was reported to move through properties and fencing was damaged or flattened during major flood events.

An ILSAX model was used and results suggest that the current capacity of the stormwater system is approximately that for a 1 year ARI event. Rainfall data from the Enfield rainfall station for the August 1986 event is included in the report.

The report presents the findings of the investigation into the flood problems in the High Street study catchment. Properties in the low points of Highgate Street, Long Street, Mount Street, Cameron Street, Hunter Street and Mintaro Avenue would receive significant overland flows whenever storm runoff exceeds the capacity of the underground pipe system.

A large number of property owners on the low (southern) side of Long Street (No's. 36– to 62) have reported various degrees of flooding problems. The resident at 232 Homebush Road reported substantial general property inundation, garage inundation and above floor level flooding. Residents of No. 107 and No. 109 Wallis Avenue were able to identify approximately four occasions (over their forty years of residency) when stormwater had ponded to such a depth at the sag point that it overtopped the footpath and caused some property inundation. The flood damage to the properties was over $30,000.

Apart from direct damage to private properties, it would be expected that in a major storm overland flows would cause damage to public property and constitute potentially hazardous conditions for children, elderly persons as well as for light vehicles (both stationary and moving).

2.4.5. Strathfield Local Flooding Issues, Stormwater Drainage Study, Volume 1, Main Report, March 1997 (Reference 6)

Kinhill Engineers Pty Ltd investigated flooding problems at six different locations within the Strathfield Council LGA and identified a number of mitigation measures which were arranged into order of priority.

Only one location investigated (*Location F*) flows into the Cooks River where it reviewed properties at the low points between High Street and Long Street (East of Homebush Road).

In order to determine existing flood conditions, Council provided ILSAX models of the various catchments which were refined for the purposes of the study. A single rainfall data file was used for all catchments.

At the low points in Long Street significant bypass flows were identified for the 1 year ARI event. Upstream of this point, Cross Street was identified as a major source of overland flows. Upgrading the inlet capacity at Mintaro Avenue was identified as a potential mitigation measure for local flooding issues.

The capacity of the stormwater system downstream of Wallis Avenue was found to be dependant on the level in the Cooks River. The main problem identified for Location F was found to be the inadequate inlet and pipe capacities upstream of Long Street. The existing pipe between Long Street and High Street was found to have a capacity for a 20 year ARI event; however the inlet capacity was estimated to be only enough for a 1 year ARI event.

Based on Kinhill's Report, Council constructed twenty new inlet pits at the kerb line, twelve grated drains and ten lintel inlet drainage pits at the front of Council's footpath on the southern side of Long Street. Two new drainage lines were also constructed.

2.4.6. Intermodel Logistics Centre at Enfield – Environmental Impact Statement, Hydrology and Hydraulics, June 2005 (Reference 7)

This study was prepared by SKM and investigated the impact of a proposed development within the former Enfield Marshalling yards site in regards to stormwater runoff. The study investigated both flooding from Coxs Creek as well as local drainage for various design events. A large part of the hydrologic detail in this report was based on a previous 1993 Public Works Department study (Reference 8) termed Enfield Marshalling Yard Stormwater Management Concept (not reviewed as part of this present study).

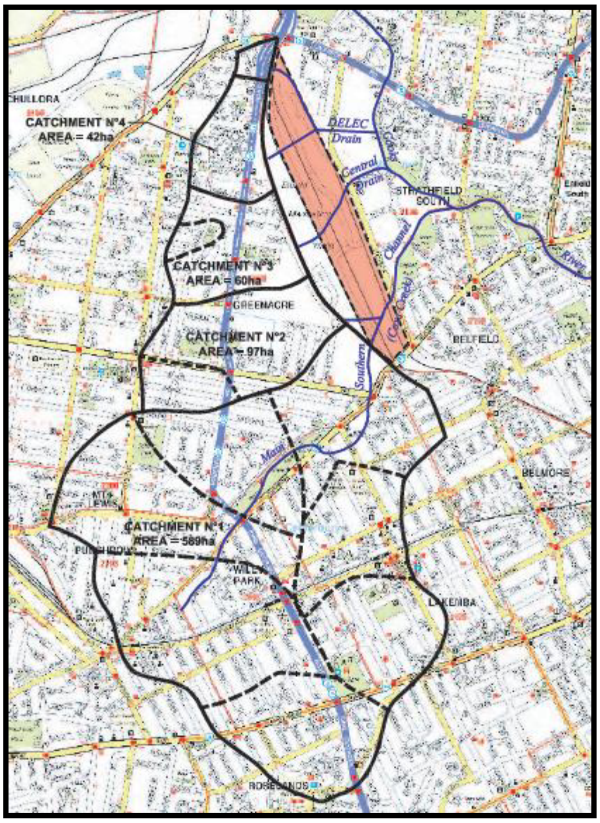
Design flows for the four upstream catchments (refer copied figures from Reference) entering the yards were calculated using the RAFTS hydrologic model with key features of the data and results provided in Table 2.

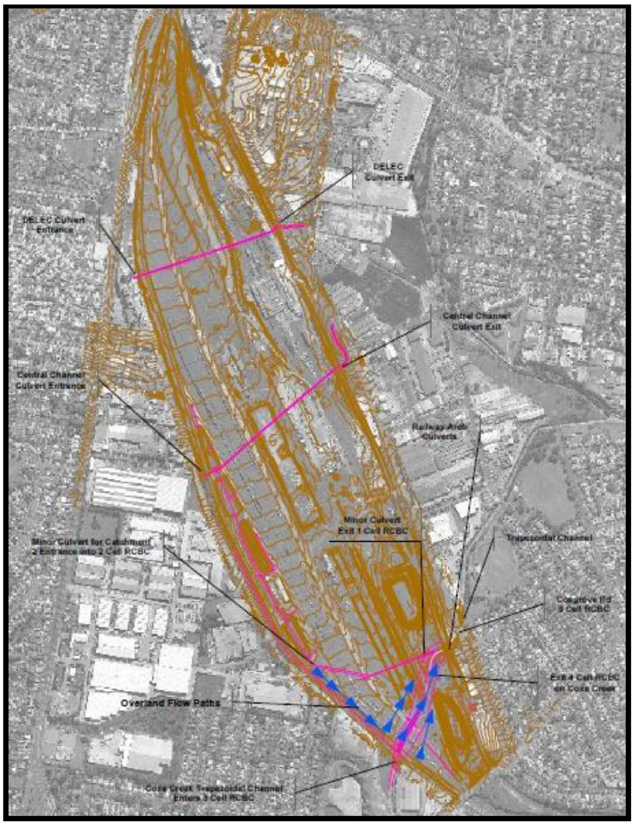
Table 2: Key Features of Contributing Catchments to Enfield Marshalling Yards

	Catchment (refer figures below)			
	1 (Coxs Creek)	2	3 (central)	4 (northern)
Catchment Area (ha)	589	97	60	42
10 year ARI flow	$124m^3/s$	$22m^3/s$	$16m^3/s$	$13m^3/s$
20 year ARI flow	$142m^3/s$	$25m^3/s$	$18m^3/s$	$14m^3/s$
100 year ARI flow	$186m^3/s$	$33m^3/s$	$23m^3/s$	$19m^3/s$
Approx. culvert dimensions (m) through yards	4 cell 2.4 to 2.8m (varies) by 1.7m (at entrance only 3 cell)	1 cell 3.1 by 1.6m connects to main channel within site	1 cell brick arch 1.5 by 1.5m	1 cell brick arch 2 by 1.8m
Capacity of culverts	$52m^3/s$	$14m^3/s$	$4m^3/s$	$15m^3/s$
100 year ARI Excess flow	$134m^3/s$	$19m^3/s$	$19m^3/s$	$4m^3/s$

Table 2 indicates that in the 100 year ARI event in Coxs Creek the capacity of the culverts is exceeded by $134m^3/s$ (2.5 times the capacity of the culverts).

The purpose of the report was primarily to assess the likely stormwater quantity and quality impacts of re-developing the site as an intermodal logistics centre where shipping containers are transferred between road and rail. A detailed hydraulic model (Mike-11) was used to establish design flood levels for the Coxs Creek overland flow across the site. For Catchments 3 and 4 (Catchment 2 overland flows enter Coxs Creek) the report indicates that any overland flow is contained upstream of the site or within the site (i.e no overflow exits from these two catchments from the site). There is no substantiation for this assumption in the report. The report concluded that re-development would produce no significant impact on stormwater quantity or quality.





Note: Above figures taken from Figures 3 and 10 from Reference 7

2.4.7. Flood Study for Proposed Industrial Subdivision Development at Former Enfield Brickpit Site, Juno Parade Greenacre, January 2007 (Reference 9)

This study was conducted by Buckton Lysenko and investigates the impact of the proposed subdivision development on flood levels. The area of the site is approximately 0.084 km^2 and adjoins Coxs Creek on its eastern boundary.

Flood discharges and levels were determined for the Coxs Creek catchment using the RAFTS and EXTRAN computer models. At the downstream property boundary stormwater is conveyed by a three cell (2650 mm wide and 1650 mm high) box culvert under the Enfield Marshalling Yards.

The study indicates that flow breaks out from the Coxs Creek channel across the railway yards at a height of 15.32 m AHD. The proposed development included a grass lined floodway to convey the flows that enter the site from Juno Parade and the modelling was reported to cause minimal impact on flood flows and levels; however an increase in levels of 80mm was determined near the houses on Juno Parade for the 100 year ARI event.

2.4.8. Addendum to Flood Study for Proposed Industrial Subdivision Development at Former Enfield Brickpit Site, Juno Parade Greenacre, June 2007 (Reference 10)

In response to concern from Strathfield Municipal Council regarding the 80 mm increase in flood levels reported in Reference 9, Buckton Lysenko conducted a flood study on an alternative proposed development

The impact of the revised development was assessed by modifying the existing HEC-RAS model and using a DRAINS model to aid in the design of the internal drainage network. However, it was noted in the study that DRAINS underestimates flow in pipes as it cannot account for the head of water above the ground surface.

The key outcomes that allowed the proposed development to proceed were:

- Inclusion of a 750mm diameter pipe under the proposed grass lined channel that conveys the flows that enter the site from Juno Parade,
- Modification of the proposed earthworks to ensure unimpeded overland flow,
- There was no adverse impact on other floodplain users.

2.4.9. 11 Cameron Street Strathfield Flood Study, June 2007 (Reference 11)

Bewsher Consulting investigated flooding through the property at 11 Cameron Street, Strathfield for a proposed redevelopment. The land is in a natural depression and the proposed development includes an underground car park. The required capacity of a 3 m wide floodway on the western border of the property was assessed as well as the impact of upgrading the

Council owned pipe through the property.

In order to assess the flooding conditions the ILSAX model from the High Street Catchment Study, 1994 (Reference 5) was used to obtain flows into the relevant pits. A HEC-RAS model was used in conjunction with a HGL assessment for the pipelines.

2.4.10. Trunk Drainage Strategy for Industrial Development Site at 34-48 Cosgrove Road Enfield, October 2007 (Reference 12)

The subject site is located on the eastern side of Cosgrove Road, with a southern frontage to Cleveland Street. The site adjoins the Sydney Water concrete stormwater channel known as the Cooks River on its eastern boundary. Council's twin 1500mm stormwater drainage pipes on the north and single 1500mm stormwater drainage pipe on the south side traverses the site.

As part of the redevelopment proposal for the site the applicant applied to relocate Council's 1500 mm stormwater drainage pipes to a new location suitable for future subdivision and upgrade the pipes.

This report was prepared to investigate the impacts of the proposed upgraded trunk drainage system through the site.

Under the existing conditions, stormwater runoff from upstream crosses under Cosgrove Road in the west in twin 1500 mm pipes and enters the inlet arrangement adjacent to Cosgrove Road. The combined pipe and overland flow will then be conveyed through the northern newly constructed triple cell 1500 mm high by 1800 mm wide box culverts.

The natural open channel upstream of Council's twin 1500 mm drainage pipes in Cosgrove Road has been replaced with a 1500 mm high by 2100 mm span box culvert. An overland flow path has been created through 39 Gould Street to allow for flows in excess of the capacity of the underground drainage system which will be collected by the inlet structure adjacent to the western boundary of 34/48 Cosgrove Road.

Downstream, north of Cleveland Street, flows enter the newly constructed 1500 mm high by 2400 mm span box culvert on the southern side of the site.

The southern conduit system allows ponding to develop in the Cosgrove Road low point adjacent to Cleveland Street to the south, with overland flows during larger events splitting between the existing open channel and the Cleveland Street flow path.

2.4.11. Cooks River Flood Study, February 2009 (Reference 1)

This study was a joint venture between MWH and PB for Sydney Water and investigates the possibility of naturalising the lower and middle reaches of both Alexandra Canal and the Cooks River.

In order to assess the impact of naturalising the channels, existing flooding conditions were investigated. A hydrologic model (WBNM) and a hydraulic model (TUFLOW) were developed and design flood levels determined. The maps indicate that numerous properties adjacent to Coxs Creek and the Cooks River are inundated by floodwaters. The hydraulic model used a grid resolution of 7m by 7m (i.e the smallest unit of topography described in the model).

Cross-section data for the Cooks River from Botany Bay to upstream of Burwood Road was used in conjunction with Airborne Laser Scanning (ALS) survey. Coxs Creek was modelled as a one dimensional element 1D (ESTRY) from immediately downstream of the Enfield Marshalling yards to the Cooks River. The Cooks River was modelled in 2D from Botany Bay to the Centenary Drive bridge within Strathfield Golf Course.

The hydrologic model was calibrated to flows from the 1994 Cooks River Floodplain Management Study (Reference 13) and the TUFLOW model calibrated to recorded flood levels. Flood contours and extents were provided for the 2 year, 20 year and 100 year Average Recurrence Interval (ARI) and Probable Maximum Flood (PMF) design events. An analysis was also undertaken into the likely impacts of a climate change induced increase in design rainfalls.

3. AVAILABLE DATA

The first stage in the investigation of flooding matters is to establish the nature, size and frequency of the problem. On large river systems such as the Hawkesbury River there are generally stream height and historical records dating back to the early 1900's, or in some cases even further. However, in small urban catchments such as the Cooks River and Coxs Creek there are no stream gauges or official historical records available. A picture of flooding must therefore be obtained from an examination of previous reports, rainfall records and local knowledge. For this reason, a comprehensive data collection exercise was undertaken. Past reports are summarised in Section 2.

3.1. Source of Data

Table 3 lists the data provided, reviewed and used for the hydrologic and hydraulic analyses.

Table 3: Data Sources

Type of Data	Purpose	Format provided (Source)	Format Stored
Location, description and invert depths of pits and pipes	Establish DRAINS model	Excel (Strathfield Municipal Council)	Excel and GIS
Ground levels from ALS data	DRAINS model and TUFLOW model	GIS (Strathfield Municipal Council)	GIS and TUFLOW model
GIS information (easements, cadastre, drainage pipe layout)	DRAINS and TUFLOW modelling	GIS (Strathfield Municipal Council)	GIS
Design rainfall	DRAINS model	Strathfield Municipal Council Stormwater Management Policy	DRAINS
Recorded flood data	Flood history	Various reports	GIS
Hydrology and hydraulic parameters	Establish DRAINS and TUFLOW models	Strathfield Municipal Council Stormwater Management Policy	n/a

A rigorous calibration of the hydrologic/hydraulic models adopted for the present study was not possible due to the lack of suitable data and as there is no stream gauge in the catchment. Information on past flood records is presented on Figure 4. These records are from the late 1980's to early the 1990's and have been obtained from resident complaints collected as part of previous studies. It is unrealistic to assume that there was no flooding prior to or post this period but rather that records are just not available. Thus it is not known if drainage has been a continuing issue in the study area.

3.2. Ground Levels – ALS data

Ground level survey was available from Airborne Laser Scanning (ALS) spot levels provided by Strathfield Municipal Council (Figure 7). This survey comprised ground levels at approximately 1 m to 2 m intervals. The data has an assumed vertical order of accuracy of ±0.15 m. The accuracy of the ALS data can be influenced by the presence of open water or vegetation (tree or shrub canopy) at the time of survey. Within the study area there is limited vegetation or open water therefore the ALS is expected to be a reliable representation of the natural surface. No independent check was undertaken to verify the ALS.

The ALS was used to create the Digital Elevation Model (DEM) used in TUFLOW modelling and for obtaining surface levels for inlet pits in DRAINS.

3.3. Historical Rainfall

3.3.1. Overview

Rainfall data is recorded either daily (24hr rainfall totals to 9:00am) or continuously (pluviometers measuring rainfall in 0.5 mm rainfall increments). Daily rainfall data have been recorded for over 100 years at many locations within the Sydney basin. In general, pluviometers have only been installed since the 1970's. Together these records provide a picture of when and how often large rainfall events have occurred in the past.

However, care must be taken when interpreting historical rainfall measurements. Rainfall records may not provide an accurate representation of past events due to a combination of factors including local site conditions, human error or limitations inherent to the type of recording instrument used. Examples of limitations that may impact the quality of data used for the present study are highlighted in the following:

- Rainfall gauges frequently fail to accurately record the total amount of rainfall. This can occur for a range of reasons including operator error, instrument failure, overtopping and vandalism. In particular, many gauges fail during periods of heavy rainfall and records of large events are often lost or misrepresented.
- Daily read information is usually obtained at 9:00am in the morning. Thus if the storm encompasses this period it becomes “split” between two days of record and a large single day total cannot be identified.
- In the past, rainfall over weekends was often erroneously accumulated and recorded as a combined Monday 9:00am reading.
- The duration of intense rainfall required to produce overland flooding in the study area is typically of 1 to 2 hour duration (though this rainfall may be contained within a longer period of rainfall). This is termed the “critical storm duration”. For a larger catchment (such as the Parramatta River) the critical storm duration will be longer. For the study area a short intense period of rainfall can produce flooding but if the rain stops quickly (as would be typical of a thunderstorm), the daily rainfall total may not necessarily reflect the magnitude of the intensity and subsequent flooding. Alternatively the rainfall may be relatively consistent throughout the day, producing a large total but only minor flooding. It is interesting to note that the last major flood on the Cooks River was in November 1961 but subsequently there have been several storms that have caused flooding in the study area but not in the Cooks River or Coxs Creek main channels.
- Rainfall records can frequently have “gaps” ranging from a few days to several weeks or even years.
- Pluviometer (continuous) records provide a much greater insight into the intensity (depth

vs. time) of rainfall events and have the advantage that the data can generally be analysed electronically. These data have much fewer limitations than daily read data. The only pluviometer station of interest for this study is the Potts Hill (Reservoir) station which has data available from 1945. Pluviometers can also fail during storm events due to the extreme weather conditions.

Rainfall events which cause overland flooding (as opposed to mainstream flooding) in the Cooks River and Coxs Creek catchment are usually localised and as such are only accurately "registered" by a nearby gauge. Gauges sited even only a kilometre away can show very different intensities and total rainfall depths.

3.3.2. Available Rainfall Data

Table 4 presents a summary of the official rainfall gauges (provided by the Bureau of Meteorology) located close to or within the catchment. There may also be other private gauges in the area (bowling clubs, schools) but data from these have not been collected as there is no public record of their existence. Figure 2 indicates the locations of the rainfall gauges closest to the study area.

Table 4: Rainfall Stations

Number	Name	Opened	Closed	Type	Source
66050	Potts Hill Reservoir	Feb-1895	Jan-2009	Daily	BOM
66164	Rookwood (Hawthorne Ave)	Jan-1945	-	Daily	BOM
66076	Roselands	Jan-1949	-	Daily	BOM
66070	Strathfield Golf Club	Jan-1952	-	Daily	BOM

3.3.3. Analysis of Rainfall Data

Generally in these types of studies an analysis of the pluviometer data is undertaken for each historical event to place the magnitude of past storm events in some context. However this was not undertaken for this study as it was considered that the nearest pluviometer (Potts Hill) would not be representative of the rainfall over the study area as it is approximately three kilometres from the study area.

3.3.4. Design Rainfall

Design rainfalls were obtained from Strathfield Council's Stormwater Management Code with temporal patters obtained from Australian Rainfall and Runoff (Reference 14). Probable Maximum Flood (PMF) design rainfall depths were obtained from Reference 15.

3.4. Downstream Boundary Condition

Analysis of overland flow using a hydraulic model requires that a downstream tailwater be included. Assuming the peak level of the respective design event in the Cooks River or Coxs Creek channel is unduly conservative as it is unlikely that both events (overland and mainstream flooding) would be coincident. In the absence of any joint probability analysis the 2 year ARI water level in the Cooks River and Coxs Creek (taken from Reference 1) was adopted as the downstream water level. Thus this approach assumes that there is some coincident flooding in the main channel. It should be noted that within the immediate overbank areas of the main channel the design flood level will generally (at least for all major events) be from mainstream flooding rather than overland flooding and thus the accuracy of the tailwater level is of little importance.

3.5. Historical Flood Information

3.5.1. Overview

A data search was carried out to identify the dates and magnitudes of historical floods. The search concentrated on the period since approximately 1970 as prior data to this date would generally be of insufficient quality and quantity for model calibration. Unfortunately there are no stream height gauges in the catchment or any other means of reliably determining the level of past flood events so the following sources were used:

- Strathfield Municipal Council records,
- previous reports,
- detailed review of rainfall records (Section 3.3) to establish the likely dates of flooding,
- local residents.

3.5.2. Information from Council Records and Previous Reports

In References 2 and 5 questionnaires were sent to residents. This identified a major flood event in Augusta, High and Long Streets (refer Section 2.4.2 for further details) on 5th August 1986 with other major events on 11th March 1991 and the first week of February 1990. There was little consistency throughout the catchment regarding the date of the worst flood event. A summary of reported flooding on various streets is shown in Table 5.

Table 5: Historical Flood Information from Reference 2

Street	Incidences of above floor inundation	Incidences of minor flooding	Dates when flooding recorded			
			Aug-86	Feb-90	Jan-89	Jan-96
High Street	1	6	y	y	y	y
Long Street	0	17	y	y	y	y
Homebush Road	1	2	y	n	n	n
Augusta Street	5	6	y	y	y	n
Palmer Avenue	0	2	y	n	n	n
Wallis Avenue	0	9	y	y	n	n
Glenarvon Street	0	5	y	y	n	n
Chalmers Road	0	3	y	y	n	n
Gelling Avenue	0	10	y	y	n	n

Strathfield Municipal Council provided information on the September 1995 and January 1996 storm events and this is shown on Table 6.

Table 6: Historical Flood Information from Council Records

Location	Aug-86	Jan-89	Feb-90	Sep-95	Jan-96	Useable for calibration
1 Palmer Avenue	Property inundation					
10 Telopea Avenue	Property flooded by 1.0 m, floor by 0.15 m					1986
107 Wallis Avenue	Property inundation		Property inundation			
109 Wallis Avenue	Property inundation				Water flowed into garage	
14 Gelling Avenue	Property inundation		Property inundation			
155 Homebush Road	Property inundation					
157 Homebush Road	Property inundation					
16 Gelling Avenue	Property inundation					
18 Gelling Avenue	Property inundation		Property inundation			
2 Glenarvon Street	Property inundation				Property inundation	
2 Palmer Avenue	Property inundation		Property inundation			
20 Amaroo Avenue	Property inundation					
20 Gelling Avenue	Property inundation		Property inundation			
23 Palmer Avenue	General property inundation					
232 Homebush Road	Above floor level					1986
26 Hunter Street	Over 1.0 m of water at the end of Kingsland Rd					1996
29 Elliot Street	Water through Bark Huts Reserve up to 1.0 m deep					1996
32 Gelling Avenue	Property inundation					
32 The Causeway	Water from adjacent property and road					
38 Hebe Street				Flow through properties from Hebe St		
39 Augusta Street	Property inundation					
4 Glenarvon Street	Property inundation		Property inundation			
4~7 Roberts Road				Flow from SRA property		
41 Augusta Street	Above floor level					1986
46 Long Street	Property inundation					
48 Long Street	Property inundation					

5 Glenarvon Street	Property inundation		Property inundation			
50 Long Street	Property inundation				Property inundation	
51 High Street	Property inundation	Property inundation	Property inundation		Property inundation	
52 Augusta Street	Above floor level					1986
52 Long Street	Property inundation	Property inundation	Property inundation		Property inundation	
53 High Street	Above floor level	Property inundation			Property inundation	1986
53 Long Street	Property inundation				Property inundation	
53 Wallis Avenue	Property inundation					
54 Long Street	Above floor level					1986
56 Long Street		Property inundation	Property inundation		Property inundation	
57 High Street	Property inundation					
58 Long Street	Property inundation					
59 Wallis Avenue	Property inundation					
6 Newton Road				Flooded basement		
61 Wallis Avenue	Property inundation					
63 Augusta Street	Above floor level		Above floor			1986, 1990
63 Wallis Avenue	Property inundation					
65 Augusta Street	Above floor level	Property inundation	Property inundation			1986
67 Augusta Street	Property inundation	Property inundation	Property inundation			
7 Cave Road	Water up to doorway of newsagency					1986
7 Gelling Avenue	Property inundation		Property inundation			
7 Long Street	Property inundation		Property inundation		Property inundation	
72 Wallis Avenue	Property inundation					
76 Wallis Avenue	Property inundation					
81 Chalmers Road	Property inundation		Property inundation			
81 Wentworth Street			Flow through properties from Hebe St			
91 Chalmers Road	Property inundation					
Ada Avenue (near Boden & Melville Ave)				Road flooded to approx 0.25 m		1986
Cosgrove Road (near Hope Street)				Flow from Enfield Marshalling Yards to Cosgrove Rd		
Pemberton Street (south end)				Water on road 0.1 m, from Pemberton to Melville Sts		

3.5.3. Community Response - Present Study

A Community Information Sheet (Appendix C) was sent to over 770 residents in July 2009 to areas that had experienced flooding problems within the study area in the past. This sheet advised them of the study and requested residents to send any flood information (photographs, description, peak levels etc.) they thought relevant to the study.

The mail-out received a very poor response and WMAwater only received three phone calls from interested residents. These consisted of two parties who described their own experience of flooding as well as providing photographs and another party who wished to understand how the present Flood Study would address re-development planned on Cosgrove Road and the Enfield Marshalling Yards.

Due to the low number of respondents to the Community Information Sheet, a Questionnaire (Appendix D) was sent to 214 households (Figure 5a) which had previously responded to flooding issues. The results of the questionnaire are provided on Figure 5b and in addition a set of photos from a December 2007 storm event for 12 Cameron Street was obtained (refer Appendix B).

3.6. Pit and Pipe Details

Details of the pit and pipe dimensions were obtained from Council's stormwater assets database. The physical details included:

- Coordinates of each pit,
- Linkage between pits,
- Pipe dimensions,
- Pit details (type of pit, inlet type and dimensions, depth to invert).

Where all this information was not available from the database it was obtained by Council from site inspection and from StreetView in Google Maps (provides the location of pits and inlet details). The surface levels of pits were obtained from the ALS.

4. APPROACH ADOPTED

4.1. General

A diagrammatic representation of the Flood Study process is shown in Diagram 1. The urbanised nature of the study area with its mix of pervious and impervious surfaces, and existing piped and overland flow drainage systems has created a complex hydrologic and hydraulic flow regime. A hydrologic/hydraulic model (DRAINS – Reference 16) was established for the entire catchment and used to create flow boundary conditions for input to a two-dimensional unsteady flow hydraulic (TUFLOW – Reference 17) model. The TUFLOW hydraulic model assessed the runoff passing through the stormwater network and floodplain by using the channel survey details, ALS ground height data and flows determined from the DRAINS model.

To ensure confidence in the results, both models require calibration and verification against observed historical events. In an urban drainage situation such as the Cooks River and Coxs Creek catchment there is rarely sufficient historical flood data available to permit either a flood frequency approach or a rigorous calibration of hydrologic and hydraulic models using a rainfall and runoff approach.

With the limited amount of flood height data available and given the lack of any stream gaugings, the parameters adopted in the model were based on engineering judgement and experience with sensitivity analysis undertaken to assess the impacts of different modelling assumptions. The adopted TUFLOW model was then used to quantify the design flood behaviour for a range of design storm events up to and including the Probable Maximum Flood (PMF).

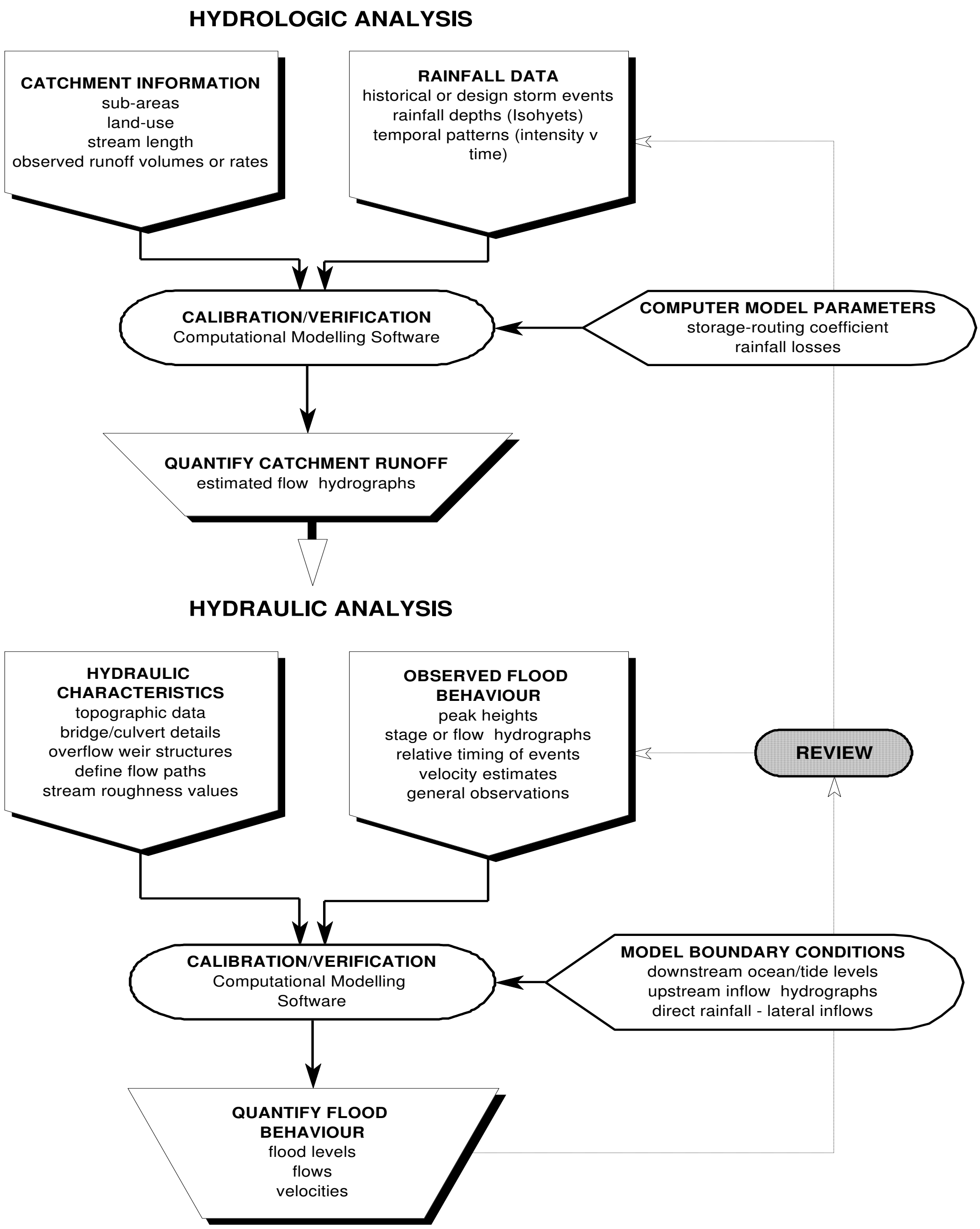


Diagram 1 Flood Study Process

4.2. Enfield Marshalling Yards and Downstream lands to the Cooks River

4.2.1. Background

The yards occupy the area between Wentworth Street and Roberts Road on the west/north, Cosgrove Road on the east and Punchbowl Road in the south. The site area is approximately 2000m in the north south direction and up to 400m in the east west direction (approximate area of 90 hectares). The site comprises railway yards as well as large areas of open space that have had extensive earthworks undertaken in the past leaving various hollows and mounds. It is obvious (Reference 7) that the site will be extensively re-developed in the near future.

Hydraulic modelling of the yards is not included within this study as it has already been completed in Reference 7. However the hydraulics and hydrology of this area are relevant for estimating the flood levels downstream and upstream. Thus this section summarises the available data and describes the adopted approach for this present study.

Raised railway embankments east of Wentworth Street at Mayvic Street and east of Roberts Road, north of Norfolk Road cause blockage of overland flow paths and create de facto detention basins (reduce peak flows downstream). Reference 12 provides a detailed description of the basins termed Boral (approximately 1000m^3) and Mayvic (approximately 13,500m^3) detention basins. It should be noted that these basins are included in the TUFLOW model as are all other “depressions” as represented by the ALS.

4.2.2. Comparison of References 7 and 12

Reference 12 was completed in 2007 and used data from References 7 and 8 (an earlier report on which much of Reference 7 is based) however Reference 12 does not provide a comparison of results.

Both references used RAFTS as the hydrologic model and produced similar peak inflows for the 100 year ARI event (only event provided in Reference 12) for catchments 3 and 4 (refer Section 2.4.10). Both references assumed no overland flow from catchments 3 and 4 with the runoff ponding upstream of the yard (or possibly overflowing into the yards) until it exits through the culverts. Reference 12 modelled the effect of the substantial volume of floodplain storage upstream of the yards whilst it would appear that Reference 7 did not. For this reason whilst the 100 year ARI peak inflows from catchments 3 and 4 (downstream of Roberts Road) are virtually identical, Reference 12 estimates a 20% reduction in the peak flows due to the significant upstream storage.

There is also a significant difference in the assumed capacity of the culverts under the yards, although both assumed a 2020 mm by 1840 mm box culvert for catchment 4 and a 1500 mm by 1500 mm brick arch culvert for catchment 3.

5. HYDROLOGIC MODEL

5.1. DRAINS Background

DRAINS is a hydrologic/hydraulic model that can simulate the full storm hydrograph and is capable of describing the flow behaviour of a catchment and pipe system for real storm events, as well as statistically based design storms. It is designed for analysing urban or partly urban catchments where artificial drainage elements have been installed.

The DRAINS model is broadly characterised by the following features:

- the hydrological component is based on the theory applied in the ILSAX model which has seen wide usage and acceptance in Australia,
- its application of the hydraulic grade line method for hydraulic analysis throughout the drainage system,
- the graphical display of network connections and results.

DRAINS generates a full hydrograph of surface flows arriving at each pit and routes these through the pipe network or overland, combining them where appropriate. Consequently, it avoids the "partial area" problems of the Rational Method and additionally it can model detention basins (unsteady flow rather than steady state).

Runoff hydrographs for each sub-catchment area are calculated using the time area method and the conveyance of flow through the drainage system is then modelled using the Hydraulic Grade Line method. Application of the Hydraulic Grade Line method is recommended for the design of pipe systems in AR&R (Reference 14). The method allows pipes to operate under pressure or to "surcharge", meaning that water rises within pits, but does not necessarily overflow out onto streets. This provides improved prediction of hydraulic behaviour, consistency in design, and greater freedom in selecting pipe slopes. It requires more complicated design procedures, since pipe capacity is influenced by upstream and downstream conditions.

However, DRAINS cannot adequately account for an elevated downstream tailwater level which would drown out the lower reaches of a drainage system (it can if the upstream pit is above the tailwater level but not if it is below). For this reason flooding within reaches affected by elevated water levels is more accurately assessed using the TUFLOW model.

It should be noted that DRAINS is not a true unsteady flow model and therefore does not account for the attenuation effects of routing through temporary floodplain storage (down streets or in yards).

5.2. Input Data

An extensive amount of data was required to establish the DRAINS model including pipe size, length, slope, pit type, depth, inlet type, location, surface and invert levels, catchment characteristics (catchment area, % imperviousness, time of concentration, etc.), design rainfall and overland flow-paths.

The information was obtained from various sources and collated into a spreadsheet for input to DRAINS. The database was expanded to include relevant DRAINS input parameters such as reference names and pipe connectivity information. Sub-catchment areas were derived using the ground contours within the GIS (Figure 10).

The following provides a summary of the source of the data and any qualifications regarding its accuracy.

Pit Location and Type: Co-ordinates were available from Strathfield Municipal Council's drainage database.

Figure 8 shows all the pits (inlet pits and junctions) located in the study area and modelled in DRAINS. It should be noted that there are other pits and pipes within the study area but these were considered too small to be modelled in DRAINS (generally < 300mm).

All surface inlet pits were classified as on-grade surface inlets with the overflow diverted to a downstream reach.

Junction pits do not have inlets to allow surface or bypass inflow and are typically where upstream branches combine or where two different sized pipes join or where there is a significant bend in the pipe. Junction pits were modelled as sealed pits without the ability to surcharge. A limitation of this method is that the pit is unable to represent surcharging, should a pit cover "blow off" under a highly pressurised pipe system.

Pit Surface Levels: Surface levels were obtained from the ALS and taken as the lowest data point within a 2 m radius of the pit.

Grate and Inlet Details: The grate and inlet type and size were taken from Strathfield Municipal Council's database. In accordance with Council's policy:

- on-grade pits with lintel openings were assigned a blockage factor of 10%,
- on-grade pits with grate openings were assigned a blockage factor of 30%,
- inlet capacities were specified based on Hornsby Council inlets as provided in DRAINS.

Pit Naming Convention: The naming convention was provided by Strathfield Municipal Council. Pits which were un-named were labelled with a prefix of 'WMA' (e.g. WMA1) for the purposes of the model. Strathfield Municipal Council was provided with a spreadsheet showing the pit names used in the DRAINS model and the names on Council's database as at October 2010.

Pipe Size, Location and Depth to Invert: These were obtained from Strathfield Municipal Council's database. Invert levels of pipes were adjusted where required to ensure that all pipes have a positive grade (a requirement of DRAINS). Pipe slopes were based on the assumed pipe inverts and the pipe distance (calculated using the pit coordinates).

Pit Connectivity: This information was obtained from Strathfield Municipal Council's database.

Catchment areas: A sub-catchment area is specified within DRAINS for each inlet pit and labelled with the prefix "a" followed by the pit name. Sub-catchment areas were derived in GIS using the ALS contours (to define the flow paths and catchment divides) and are shown on Figure 10. For each sub-catchment area the proportion of pervious (grassed), impervious (paved), supplementary area (paved area not directly connected to pipe system - these were estimated in this study as 5% of the total catchment) were determined from field and aerial photographic inspections and shown on Figure 3 and summarised in Table 7. For residential areas (includes roads) a relatively high value was adopted to reflect the likely low infiltration capacity of suburban yards and open space areas.

Table 7: DRAINS Catchment Details

Area	Area (ha)	%
Paved Area	380.8	66
Grassed Area	169.9	29
Supplementary	28.9	5
TOTAL	**578.9**	100

Time of Concentration: The surface runoff from each sub-catchment contributing to a pit has a particular time of concentration. This is defined as the time it takes for runoff from the upper part of a sub-catchment to start contributing as inflow to the pit. It is mainly related to the flow path distance, slope and surface type over which the runoff has to travel.

The time of concentration was defined using a flow length based on the sub catchment slope and the size and shape of the contributing catchment. An additional delay lag of 2 minutes was applied to the pervious areas.

The catchment slopes were derived from inspection of the contours and it was found that the majority of the sub catchments had a slope of 2%.

Overland Flow Path: The precise route of the overland flow path is not given, only the link between the upstream and downstream inlet pits in a straight line.

Any runoff that was unable to enter a downstream pipe reach due to insufficient inlet or pipe capacity was modelled as overland flow. These overland flow paths were determined from field inspection and the ALS contour information. At each inlet pit where overland flow was possible, a downstream inlet pit was specified as the receiving destination, together with an estimated travel time.

Overland flow travel times can have a significant bearing upon the accumulated peak flows achieved further downstream. DRAINS does not route flows along overflow routes, but takes flows from one pit and places it at the downstream pit after a specified travel time. Travel time was estimated using measured flow lengths and assuming a velocity of 1 m/s. If the travel times were less than 0.1 minute they were rounded to 0.1 minute.

Ku Loss Factor: This factor was initially set at 1.5 and then DRAINS updates the values based on the results of a model run.

Design Rainfall: Strathfield Municipal Councill provided design rainfall intensities for the catchment with design temporal patterns derived from AR&R (Reference 14). Uniform depths of rainfall with zero areal-reduction factors were applied across the entire catchment.

5.3. Establishing DRAINS

The DRAINS model established for the study area included 968 sub-catchments. The drainage system defined by the model is made up of:

- runoff entry points representing surface inlet pits,
- bends, junctions or inspections locations which are termed pits with no inlet (i.e. the lid is sealed),
- underground conduits (circular pipe or box) or open channel lengths between pits, called reaches.

A number of consecutive reaches is called a branch. The pipe system "tree" structure is defined by nominating the pits where two or more branches join. The length, slope, shape and dimension of each reach are specified, as well as representative inflow characteristics (surface inlet capacity) for each inlet pit.

5.4. Adopted Model Parameters

Losses from a paved or impervious area are considered to comprise only of an initial loss (an amount sufficient to wet the pavement and fill minor surface depressions). Losses from grassed areas are comprised of an initial loss and a continuing loss. The continuing loss was calculated from an infiltration equation curve incorporated into the model and is based on the estimated representative soil type and antecedent moisture condition. It was assumed that the soil in the catchment has a slow infiltration rate potential and the antecedent moisture condition was considered to be saturated. The latter was justified by the fact that the peak rainfall burst can typically occur within a longer event that has a duration lasting days. The adopted parameters are summarised in Table 8.

Table 8: Adopted DRAINS Hydrologic Model Parameters

RAINFALL LOSSES	
Paved Area Depression Storage (Initial Loss)	1.0 mm
Grassed Area Depression Storage (Initial Loss)	5.0 mm
SOIL TYPE	3
Slow infiltration rates. This parameter, in conjunction with the AMC, determines the continuing loss	
ANTECEDENT MOISTURE CONDITIONS (AMC)	3
Description	Rather wet
Total Rainfall in 5 Days Preceding the Storm	12.5 to 25mm

5.5. Outlet Conditions

The modelled pipe system was taken to the main channel of either the Coxs Creek or Cooks River channel and it should be noted that DRAINS cannot simulate the "drowning" of pits when elevated tail-water levels are higher than the upstream pit surface level.

5.6. Model Validation

Ideally models are calibrated against observed flood information, however for the study area the insufficient quality and quantity of historical data means that a rigorous calibration is not possible. Thus the only verification possible is to compare the results with previous studies and where applicable compare estimated peak historical levels with design levels (refer Section 6.4).

A comparison between results from previous studies and those from the DRAINS model is given in Table 9.

Table 9: Comparison of Peak Flows with Previous Studies

Location	ARI (y)	Source	Reference Flow (m^3/s)	DRAINS Flow (m^3/s)	Percentage Difference
11 Cameron Street (total)	20	Reference 11	1.8	1.8	0%
11 Cameron Street (total)	100	Reference 11	2.3	2.1	-9%
p10228 (overland)	100	Reference 4	15.9	13.1	-18%
p10228 (pipe)	100	Reference 4	3.4	2.8	-18%
p10520 (overland)	100	Reference 4	27.8	24.6	-12%
p10520 (pipe)	100	Reference 4	11.1	4.7	-58%
p9168 (overland)	20	Reference 3	8.8	12.0	36%
p9168 (overland)	100	Reference 3	11.3	15.7	39%
p9168 (pipe)	20	Reference 3	2.8	2.0	-29%
p9168 (pipe)	100	Reference 3	2.7	2.1	-22%
p9196 (overland)	20	Reference 3	8.5	12.8	51%
p9196 (overland)	100	Reference 3	10.8	17.2	59%
p9196 (pipe)	20	Reference 3	4.3	2.8	-35%
p9196 (pipe)	100	Reference 3	4.5	2.8	-38%
Central Drain (total)	20	Reference 7	18.0	13.5	-25%
Central Drain (total)	100	Reference 7	23.0	17.7	-23%
DELEC Drain (total)	20	Reference 7	14.0	13.5	-4%
DELEC Drain (total)	100	Reference 7	19.0	17.7	-7%

The results are very variable with a close match at some locations but a large difference at others. There could be a variety of reasons for such differences (different contributing catchment areas, pipe hydraulics etc.) which could only be explained if the original hydrologic model was examined in detail. The DRAINS model does not model backwater effects and assumes that all pits are on-grade and therefore any additional head is not taken into consideration when pit surcharging occurs at a downstream pit.

A detailed review of the results at each location is not possible as this would require an entire review of the previous study and the data (model layout, catchment areas, model assumptions) are not available. The following provides some explanation:

- The pipe flow calculations in ILSAX (References 3 and 4) and DRAINS are different and thus differences are expected,
- For p9168 the pipe flow is lower for the present study but higher for the overland flow, thus the total (pipe and overland) between the two studies is similar. This scenario may occur elsewhere and possibly affect the results at downstream locations,
- There is no prescriptive procedure for estimating the overland flow travel time in ILSAX or DRAINS (significant factor in determining the peak flow), thus different modellers make different assumptions. In the absence of calibration data it is impossible to determine which answer is correct,
- Very little information is available regarding peak flows (pipe or overland) in urban catchments and thus it is not possible to use data from other studies to verify the results from this present or any other study.

6. HYDRAULIC MODEL

6.1. TUFLOW Background

The TUFLOW modelling package includes a finite difference numerical model for the solution of the depth averaged shallow water flow equations in two dimensions. The TUFLOW software is produced by BMT WBM (Reference 17) and has been widely used for a range of similar projects. The model is capable of dynamically simulating complex overland flow regimes. It is especially applicable to the hydraulic analysis of flooding in urban areas which is typically characterised by short duration events and a combination of supercritical and subcritical flow behaviour.

For the hydraulic analysis of overland flow paths, a two-dimensional (2D) model such as TUFLOW provides several key advantages when compared to a traditional one-dimensional (1D) model. For example, in comparison to a 1D approach, a 2D model can:

- provide localised detail of any topographic and/or structural features that may influence flood behaviour,
- better facilitate the identification of the potential overland flow paths and flood problem areas,
- inherently represent the available floodplain storage within the 2D model geometry.

Importantly, a 2D hydraulic model can better define the spatial variations in flood behaviour across the study area. Information such as flow velocity, flood levels and hydraulic hazard can be readily mapped in detail across the model extent. This information can then be easily integrated into a GIS based environment enabling the outcomes to be incorporated into Council's planning activities.

6.2. Model Establishment

Given the objectives and requirements of the study and the availability of ALS data a 2D overland flow hydraulic model is the most suitable model to effectively assess flood behaviour.

The TUFLOW hydraulic model was divided into four separate models (termed M1 to M4) for ease of use and to permit the Cooks River and Coxs Creek channel to be used as a downstream boundary condition (Figure 12). The 2D models extend from upstream of Roberts Road draining into Coxs Creek and the upper Cooks River catchment to the crossing of Punchbowl Road over the Cooks River.

A 2m by 2m 2D grid was generated from the ALS data based on the aerial photography available at the time of the study. Whilst every attempt was made to include current buildings it should be noted that this was not always possible due to the rapidly changing nature of the study area. Pit and pipe information incorporated in the DRAINS model was used to create a 1D drainage network in TUFLOW. Pipes of diameter smaller than 600mm were included in the TUFLOW model but assumed to be blocked. This assumption was based on comments from residents who indicated that blockage of pits and pipes due to leaves and debris (notably chipped bark placed in parks or in private property) occurs regularly. During the site inspected it was noted that several pits/pipes were largely blocked. Temporarily blockage may also occur during a storm as the pit entry may be restricted by a vehicle parking over the grate or leaves/silt/branches filling the inlet. It is impossible to accurately estimate the degree of blockage during a storm and for this reason a conservative approach of assuming all pipes of smaller diameter than 600mm were blocked in TUFLOW. The majority of these pipes are smaller than 450mm diameter (refer Table 1), over 50% of the total length of the pipe system in the study area comprises pipes smaller than 450mm diameter. However all pits and pipes were included in the DRAINS model.

6.3. Boundary Conditions

6.3.1. Design Inflows

Design flows from all the DRAINS sub-catchments are used as inflows into TUFLOW's 1D network. These were directly input to inlet pit locations within the 1D model. This assumes that the piped systems within the 1D model extent are capable of surcharging into the 2D domain. This assumption was necessary for the interaction between the two models.

6.3.2. Tailwater Level in the Cooks River and Coxs Creek

A downstream or tailwater level is required in the Cooks River and Coxs Creek channel to represent the downstream boundary of the model. This can be achieved in various ways and for the present study the approach of using the peak design flood level for the 2 year ARI event from Reference 1 was assumed in conjunction with the overland design flood events. This approach was considered to provide a realistic tailwater level at the time of flooding in the study area. A joint probability analysis would be required to determine a more rigorous approach and this could not be justified as part of the present study.

It should be noted that for the flood mapping an "envelope approach" has been used to determine whether the level from overland flow modelling (as part of the present study) or the level in the Cooks River and Coxs Creek (Reference 1) provides the higher flood level.

6.3.3. Roughness Co-efficient

The Manning's "n" values for each grid cell were estimated from engineering experience and applied to the 2D overland area based on the terrain shown in Table 10.

Table 10: Manning's "n" values adopted in TUFLOW

Category	Manning's "n"	Description
1	0.02	Bitumen road reserve and some car-parks
2	0.04	Short grassed areas for overland flowpath
3	0.03	Residential and urban
4	0.032	Non-bitumen road reserve

For this study it has been considered that properties adjacent to the overland flow-path boundary would not be part of the effective flow path due to the presence of fences and buildings. However inundation into these properties has been allowed in the model. High Manning's "n" coefficients within adjacent properties were adopted, in conjunction with extruding the building outlines in these areas (restricts flowpath).

6.3.4. Hydraulic Structures

Buildings have been excluded from the model as it is assumed that there is very little flow through the structures. Due to the continuing re-development of parts of the area (Cosgrove Road) it is likely that the TUFLOW grid does not exactly match the structures on the ground in all places. In areas where there was large overland flow and significant obstructions by fences and other flow restrictions these were modelled in higher detail within TUFLOW (example shown in Photo 1).

Photo 1: 51 Highgate Street fence completely blocking flow-path

6.4. Model Calibration and Verification

Ideally the TUFLOW model should be calibrated to one historical event and verified using another historical event. There should also be sufficient historical flood height data (preferably for both historical events) to define the flood gradient within the modelling extent. As there is only approximate flood level information it is not possible to undertake a rigorous calibration. This is typical of the majority of urban catchments. In Sydney (east of Parramatta) there are only two water level recorders in urban catchments typical of the study area.

In parts of the catchment the use of past historical flood height data would also be of little relevance as the flow paths have changed so much in recent times, due to the removal of buildings and fences (notably Cosgrove Road). However it is essential that the collection of flood height data from future events be undertaken by Strathfield Municipal Council to "verify" the results from this present study.

6.4.1. Historic Data

Available information from historical events includes indicative water depths and flooding obtained from the present (Section 3.5.3) and past resident surveys. Council also provided information on the September 1995 and January 1996 storm events. All the available relevant information is provided on Table 11.

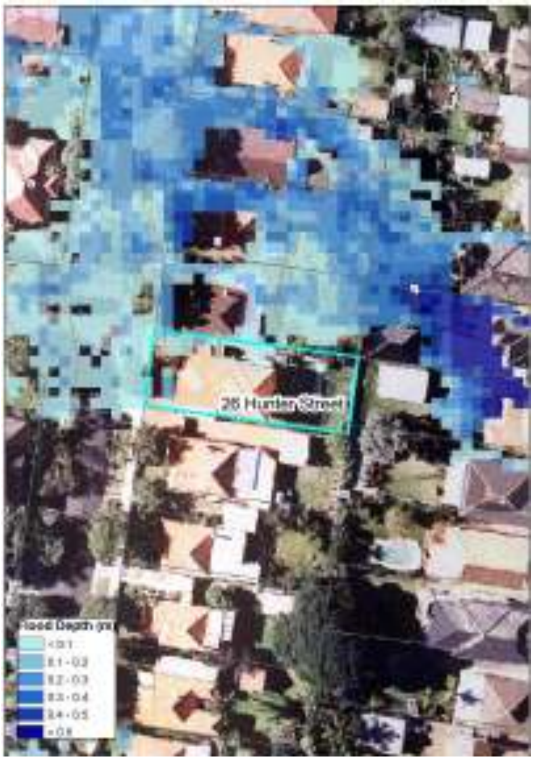
Table 11: Model Calibration Results

Location	Event	Description	Indicative depth (m) Historic	TUFLOW model 20y	TUFLOW model 100y
53 High Street	Aug-86	Above floor level by approx 0.5 m	0.80	1.31	1.35
232 Homebush Road	Aug-86	Above floor level by approx 0.5 m	0.80	0.59	0.70
52 Augusta Street	Aug-86	Above floor level*	0.50	0.47	0.53
65 Augusta Street	Aug-86	Above floor level*	0.40	0.30	0.33
63 Augusta Street	Aug-86	Above floor level*	0.40	0.23	0.27
41 Augusta Street	Aug-86	Above floor level by approx 0.5 m	0.80	0.75	0.89
Ada Avenue at Boden and Melville Streets	Sep-95	Road flooded to approx 0.25 m depth	0.25	0.23	0.24
7 Cave Road	Jan-96	Water up to doorway of newsagency	0.25	0.33	0.41
29 Elliot Street	Jan-96	Stormwater through Bark Huts Reserve up to 1.0 m deep	1.00	0.46	0.61
26 Hunter Street	Jan-96	Over 1.0 m of water in the street at end of Kingsland Road	1.00	0.24	0.24
54 Long Street	Jan-96	Above floor level by approx 0.5 m	0.50	0.38	0.44
10 Telopea Avenue	Jan-96	Property flooded by 1.0 m, floor by approx 0.15 m	1.00	0.07	0.09

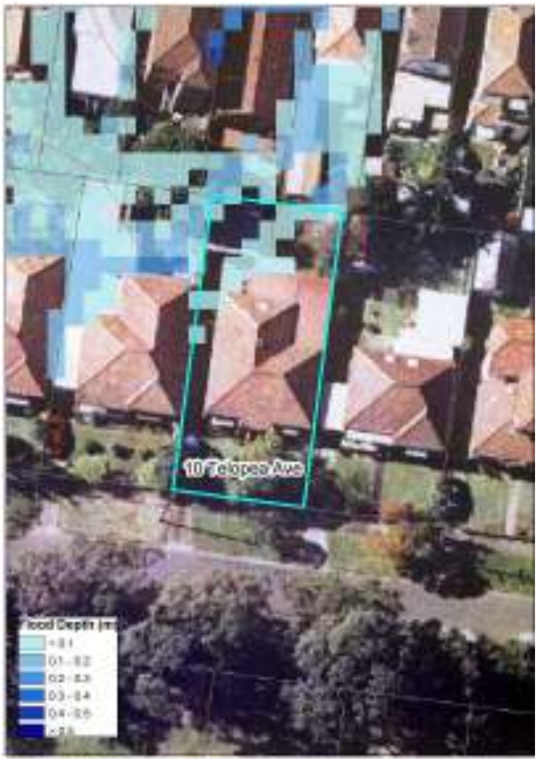
* Affected by mainstream flooding (design flood levels taken from Reference 1)

The magnitude of the historical events cannot be accurately ascertained as there is no nearby pluviometer that would provide an indication of the magnitude of the rainfall. Reference 3 indicates that the August 1986 event approximated a 20 year ARI event. The other events (January 1996 and September 1995) are probably less than a 10 or maybe a 5 year ARI events. However it should be noted that intense localised rainfall events do occur and could well have intensities that approximate a much rarer event but without some form of rainfall data it is impossible to estimate their magnitude.

The results in Table 11 indicate that the majority of depths from historic flood events are within the expected range of design flood depths. The only exceptions are the flood depths at 26 Hunter Street and 10 Telopea Ave where the recorded depths are much greater than from TUFLOW. Flood depths and extents near these two properties for the 100 year ARI event are provided below and no explanation can be provided for the magnitude of the observed depths.



26 Hunter Street



10 Telopea Avenue

6.4.2. Comparison with Previous Studies

Design flows at the downstream end of the Augusta Street (Reference 4) and High Street (Reference 5) catchments have been compared in Table 12.

Table 12: Comparison of Design Peak Flows

		Peak Flow (m^3/s)	
Location	**Design Event**	**Reference**	**TUFLOW**
High Street (Reference 5)	10y ARI	13.1	14.6
High Street (Reference 5)	20y ARI	17.1	17.3
High Street(Reference 5)	100y ARI	26.3	24.0
Augusta Street (Reference 4)	20y ARI	13.0	11.9
Augusta Street (Reference 4)	100y ARI	16.0	13.3

The differences between the current study and previous studies are due to different assumptions in the hydraulic models used. The previous studies used an ILSAX model, which assumes a constant overland flow velocity of between 2 m/s and 3 m/s and a pit inlet capacity of $0.2m^3/s$. As the current TUFLOW model is 2D it includes a more accurate estimate of the routing effects and temporary floodplain storage.

6.4.3. Comparison of Peak Pipe Flows in DRAINS and TUFLOW

Table 13 provides a comparison between the 20 year ARI peak pipe flows in DRAINS and in TUFLOW.

Table 13: Comparison of Peak Flows in Pipes

Name	Size (mm)	Flow (m^3/s) DRAINS	Flow (m^3/s) TUFLOW	Flow (m^3/s) Difference	Velocity (m/s) DRAINS	Velocity (m/s) TUFLOW	Velocity (m/s) Difference
p10414	600	0.7	0.8	8%	2.5	2.7	8%
p12038	600	0.5	0.6	10%	1.9	2.1	10%
p18060	675	0.4	0.8	53%	1.1	2.3	53%
p11072	750	0.7	0.6	-20%	1.5	1.3	-20%
p7038	750	0.7	1.3	42%	1.7	2.9	42%
p11204	750	0.7	0.9	26%	1.5	2.0	26%
p9076	825	1.3	1.9	30%	2.5	3.5	30%
p11132	900	0.7	0.9	29%	1.1	1.5	29%
p11254	1050	1.3	2.0	34%	1.5	2.3	34%
p12142	1050	1.3	2.2	38%	1.6	2.5	38%
p10456	1200	1.7	2.6	33%	1.5	2.3	33%
p8035	1200	0.9	1.6	41%	0.8	1.4	41%
p8220	1350	2.8	3.4	18%	1.9	2.3	18%
p9210	1350	3.2	4.1	23%	2.2	2.9	23%
p9168	1350	2.0	3.1	35%	1.4	2.2	35%
p10136	750 x 700	0.4	0.4	10%	0.7	0.8	10%
p10176	900 x 825	1.0	1.9	45%	1.4	2.6	45%
p10504	2000 x 1350	4.2	5.9	28%	1.6	2.2	28%
p10522	2000 x 1800	4.7	8.4	44%	1.3	2.3	44%
p10232	2100 x 1200	2.8	4.7	41%	1.1	1.9	41%

The differences between DRAINS and TUFLOW are due to the treatment of overland flow and assumed headwater and tailwater conditions. The DRAINS model requires explicitly defined overland flow routes whereas TUFLOW determines these based on the ground topography. Different assumptions are made in each model for the headwater and tailwater conditions. It is also possible that different inlet capacity assumptions may influence the results.

The maximum velocity in the TUFLOW model pipe network for the 20 year ARI flood event was 3.5 m/s. The average difference between flows in the TUFLOW and DRAINS models is a 28% higher peak design flow in the TUFLOW model.

7. DESIGN FLOOD RESULTS

7.1. Overview

There are two basic approaches to determining design flood levels, namely:

- *flood frequency analysis* – based upon a statistical analysis of the flood events, and
- *rainfall and runoff routing* – design rainfalls are processed by hydrologic and hydraulic computer models to produce estimates of design flood behaviour.

The *flood frequency* approach requires a reasonably complete homogeneous record of flood levels and flows over a number of decades to give satisfactory results. No such records were available within the catchment. For this reason a *rainfall and runoff routing* approach using the DRAINS model results was adopted for this study to derive inflow hydrographs for input to the TUFLOW hydraulic model, which determines design flood levels, flows and velocities. This approach reflects current engineering practice and is consistent with the quality and quantity of available data.

7.2. Design Events

7.2.1. Design Critical Storm Duration

Initially the TUFLOW model was run for a series of design storm durations (15 minutes to 2 hours) for the 100 year ARI event. A comparison of the peak water levels at the inlet pits indicated that the critical duration (event producing the highest flood level) was the 25 minute storm duration. This duration was then adopted as the critical storm duration for all other design events except the PMF (30 minute duration adopted).

7.2.2. Design Results

A tabulation of peak flood depths for the various design events at 23 sites across the study area is shown on Table 14 (locations within the high hazard areas over Council's trunk drainage lines – these locations are **NOT** those shown on Figure 6 which refers to locations referred to in Appendix B). These results indicate that there is only a small variation in water depth between the various design events. Flood contours, extents and depths are provided on Figure 13 for the 2, 5, 10, 20, 100, 200 year ARI events and the PMF with peak height profiles provided on Figure 14.

It should be noted that properties adjacent to the banks of the Cooks River and Coxs Creek are influenced by elevated levels in the main channel (mainstream flooding as determined in Reference 1) as well as runoff emanating from the local catchment (overland flow as determined as part of this study using TUFLOW). Figure 11 provides the flood extents and contours from Reference 1 with the areas where the overland flood levels ***exceed*** *the mainstream levels shown as a separate overlay. Figure 13 represents the flood levels from overland flow with the respective design flood event obtained from Reference 1 shown as an overlay (where that overlay is unavailable the next largest event has been used).*

Table 14: Design Flood Depths (m)

ID	Location	Flood Depth (m)						
		2y	5y	10y	20y	100y	200y	PMF
1	3 Bareena Street Strathfield	0.72	0.83	0.89	0.95	1.02	1.06	1.51
2	1 Myrna Road Strathfield	0.32	0.39	0.43	0.48	0.52	0.55	0.87
3	83 Chalmers Road Strathfield	0.80	0.96	1.03	1.11	1.22	1.28	2.13
4	76 Wallis Avenue Strathfield	0.47	0.54	0.58	0.63	0.70	0.73	1.34
5	4 Glenarvon Street Strathfield	0.58	0.65	0.68	0.72	0.78	0.80	1.37
6	45 Augusta Street Strathfield	0.43	0.50	0.55	0.62	0.70	0.75	1.38
7	40-44 Augusta Street Strathfield	0.17	0.25	0.29	0.33	0.38	0.41	0.75
8	10 Mount Street Strathfield	0.64	0.69	0.71	0.75	0.80	0.83	1.22
9	12 Cameron Street Strathfield	0.35	0.42	0.45	0.48	0.53	0.56	1.08
10	18 Hunter Street Strathfield	0.25	0.29	0.31	0.35	0.39	0.41	0.69
11	28 Mintaro Avenue	0.47	0.53	0.56	0.60	0.65	0.68	1.11
12	25 Long Street	0.37	0.40	0.42	0.46	0.51	0.53	1.10
13	48 Long Street Strathfield	0.41	0.47	0.49	0.54	0.59	0.62	1.38
14	50 Long Street Strathfield	0.44	0.49	0.52	0.56	0.61	0.63	1.42
15	52 Long Street Strathfield	0.34	0.39	0.42	0.45	0.54	0.60	1.65
16	59 High Street Strathfield	0.70	0.83	0.92	1.01	1.14	1.21	2.23
17	230 Homebush Road Strathfield	0.66	0.78	0.86	0.96	1.09	1.15	2.18
18	232 Homebush Road Strathfield	0.53	0.61	0.66	0.71	0.79	0.83	1.55
19	124 Wallis Avenue Strathfield	0.79	0.85	0.90	0.95	1.09	1.15	2.10
20	126 Wallis Avenue Strathfield	0.14	0.22	0.28	0.35	0.48	0.55	1.52
21	16 Elliot Street Strathfield South	0.32	0.38	0.42	0.46	0.52	0.56	1.07
22	25 Wentworth Street Greenacre	0.28	0.34	0.44	0.58	0.84	0.91	1.59
23	Coxs Creek west of Drone Street	2.17	2.29	2.37	2.43	2.53	2.56	3.66

Note: Flood depths are indicative only and depths on the property may be higher or lower at other locations

For the purposes of floodplain risk management in NSW the floodplain is divided into one of three Hydraulic categories (floodway, flood storage or flood fringe) and two Hazard categories (Low or High). These terms are defined in Appendix A and further details of this process are provided in the NSW Government's Floodplain Development Manual (Reference18).

The Hazard categorisation was determined quantitatively based upon the available hydraulic and survey information in accordance with the provisional hydraulic hazard categorisation figures provided in the Floodplain Development Manual. As indicated in the Floodplain Development Manual this process of Hazard categorisation is **Provisional** and should be refined at a later date to reflect other factors that influence hazard (such as warning time, flood readiness, rate of rise, duration of flooding, evacuation problems, effective flood access and the type of development). The hazard categorization is provided on Figure 15 for all design events.

Definition of hydraulic categories is subjective and particularly in an urban catchment where the depths of inundation are relatively shallow and the peak flows small. However blocking a flowpath or a floodway can re direct flow onto adjoining properties and so adversely affect the adjoining property. This already occurs due to inappropriate fencing, landscaping or vegetation. Council endeavours to ensure that any new development that requires a Development Application (DA) complies with the requirements stated in Council's Flood Prone Land Policy. A flood study is not required for single residential developments.

Any filling on the floodplain or blocking of a flow path will affect flood levels elsewhere, however it is impractical for Council to monitor every development on the floodplain as many will have only a very minor impact. For the purposes of this study the following are defined as Floodways with the remainder of the floodplain defined as flood fringe (no flood storage):

- *All roads, drainage easements or parks inundated by floodwaters,*
- *All flood liable private property where runoff enters across one boundary and exits partially or fully across another.*

7.3. Sensitivity Analyses

Given the lack of reliable historical flood level data and no stream flow data available, only a very limited calibration of the DRAINS and TUFLOW models was possible. This situation is typical of the majority of urban catchments in NSW. In order to quantify the effects of varying model parameters the following sensitivity analyses were undertaken for the 100 year ARI event.

- Change in Manning's "n" in TUFLOW by +20% and -20%
- Assumed blockage in pipes in TUFLOW of 50% and 100%

The results are provided in Table 15 for 23 locations (locations within the high hazard areas over Council's trunk drainage lines – these locations are **NOT** those shown on Figure 6 which refers to locations referred to in Appendix B).

Table 15: Sensitivity Analyses - 100 year ARI Design Event

ID	Location	Existing Depth (m)	Change in Flood Depth (m)			
			Blockage		Change in "n"	
		100y ARI	50%	100%	+ 20%	- 20%
1	3 Bareena Street Strathfield	1.02	0.00	0.00	0.01	0.00
2	1 Myrna Road Strathfield	0.52	0.00	0.00	0.01	0.02
3	83 Chalmers Road Strathfield	1.22	0.09	0.15	0.01	0.00
4	76 Wallis Avenue Strathfield	0.70	0.05	0.11	0.00	0.00
5	4 Glenarvon Street Strathfield	0.78	0.04	0.07	0.00	-0.01
6	45 Augusta Street Strathfield	0.70	0.07	0.10	0.00	0.00
7	40-44 Augusta Street Strathfield	0.38	0.03	0.05	0.01	-0.01
8	10 Mount Street Strathfield	0.80	0.00	0.00	0.00	0.01
9	12 Cameron Street Strathfield	0.53	0.02	0.06	0.01	-0.01
10	18 Hunter Street Strathfield	0.39	0.02	0.03	0.01	-0.02

11	28 Mintaro Avenue	0.65	0.02	0.04	0.01	-0.01
12	25 Long Street	0.51	0.01	0.02	0.01	-0.01
13	48 Long Street Strathfield	0.59	0.01	0.06	0.02	-0.02
14	50 Long Street Strathfield	0.61	0.01	0.04	0.01	-0.02
15	52 Long Street Strathfield	0.54	0.02	0.06	0.01	-0.02
16	59 High Street Strathfield	1.14	0.02	0.07	-0.02	0.00
17	230 Homebush Road Strathfield	1.09	0.02	0.06	-0.03	0.01
18	232 Homebush Road Strathfield	0.79	0.01	0.05	0.01	0.01
19	124 Wallis Avenue Strathfield	1.09	0.05	0.11	0.02	-0.03
20	126 Wallis Avenue Strathfield	0.48	0.05	0.12	0.02	-0.02
21	16 Elliot Street Strathfield South	0.52	0.00	0.10	0.00	0.01
22	25 Wentworth Street Greenacre	0.84	0.09	0.15	-0.01	0.00
23	Coxs Creek west of Drone Street	2.53	-0.05	-0.06	0.02	-0.03

Note: Flood depths are indicative only and depths on the property may be higher or lower at other locations

The results indicate that the effect of changing the blockage or Manning's "n" produces a change in flood level of generally less than 0.05m, though up to 0.15m. Results from the blockage scenarios are generally to be expected as in the 100 year ARI event only a small proportion of the total flow is contained within the pipe system. As the above ground flow path is relatively wide (roads) an increase in flow can be accommodated with only a relatively small increase in water level.

7.4. Climate Change

In accordance with the DECC Guideline October 2007 (Reference 19), the possible effects of climate change on flooding have been investigated. The possible effects relevant to this study are an increase in ocean level and an increase in the design rainfall intensity. The guideline suggests the following scenarios be examined:

- **ocean level rise:**
  - low level ocean rise = 0.18 m,
  - medium level ocean rise = 0.55 m,
  - high level ocean rise = 0.91 m.

- **increase in peak rainfall and storm volume:**
  - low level rainfall increase = 10%,
  - medium level rainfall increase = 20%,
  - high level rainfall increase = 30%.

An increase in ocean level of 0.91m will have no measurable impact on design flood levels within the study area and for this reason the effects of sea level rise have not been considered further in this study.

A high level rainfall increase of up to 30% is recommended for consideration due to the uncertainties associated with this aspect of climate change. It is generally acknowledged that a

30% rainfall increase is probably overly conservative and that a timeframe for the provision of definitive predictions of the actual increase is unknown.

Table 16 provides an assessment of the potential increase in design rainfalls of 10%, 20% and 30% for the 100 year ARI event at the 23 locations (locations within the high hazard areas over Council's trunk drainage lines – these locations are **NOT** those shown on Figure 6 which refers to locations referred to in Appendix B). The results indicate that the *average increase* (based on a comparison of the peak level at the inlet pits) in the 100 year ARI event is:

- low level rainfall increase of 10% = +0.04m,
- medium level rainfall increase of 20% = +0.08m,
- high level rainfall increase of 30% = +0.11m.

However the results do show a significant variation between locations.

Table 16: Results of Rainfall Increase - 100 year ARI Design Event

ID	Location	Existing Depth (m)	Change in Flood Depth (m)		
			+10%	+20%	+30%
1	3 Bareena Street Strathfield	1.02	0.04	0.07	0.10
2	1 Myrna Road Strathfield	0.52	0.03	0.05	0.09
3	83 Chalmers Road Strathfield	1.22	0.05	0.11	0.15
4	76 Wallis Avenue Strathfield	0.70	0.03	0.07	0.11
5	4 Glenarvon Street Strathfield	0.78	0.02	0.05	0.07
6	45 Augusta Street Strathfield	0.70	0.04	0.08	0.11
7	40-44 Augusta Street Strathfield	0.38	0.02	0.05	0.06
8	10 Mount Street Strathfield	0.80	0.03	0.05	0.08
9	12 Cameron Street Strathfield	0.53	0.03	0.05	0.08
10	18 Hunter Street Strathfield	0.39	0.02	0.04	0.06
11	28 Mintaro Avenue	0.65	0.03	0.06	0.08
12	25 Long Street	0.51	0.02	0.05	0.08
13	48 Long Street Strathfield	0.59	0.03	0.08	0.11
14	50 Long Street Strathfield	0.61	0.02	0.06	0.08
15	52 Long Street Strathfield	0.54	0.05	0.11	0.16
16	59 High Street Strathfield	1.14	0.06	0.11	0.16
17	230 Homebush Road Strathfield	1.09	0.06	0.11	0.16
18	232 Homebush Road Strathfield	0.79	0.04	0.08	0.11
19	124 Wallis Avenue Strathfield	1.09	0.06	0.10	0.14
20	126 Wallis Avenue Strathfield	0.48	0.06	0.11	0.15
21	16 Elliot Street Strathfield South	0.52	0.04	0.08	0.11
22	25 Wentworth Street Greenacre	0.84	0.07	0.11	0.15
23	Coxs Creek west of Drone Street	2.53	0.03	0.08	0.11

Note: Flood depths are indicative only and depths on the property may be higher or lower at other locations

As expected the peak flood depths generally increase with corresponding increases in rainfall.

One of the worst flooded areas; the intersection of High and Wallis Street, experiences impacts of the order of +0.06m, +0.11m and +0.16m for the 10%, 20% and 30% increase in rainfall scenarios respectively.

7.5. Pipe Upgrades

An analysis of the pipe sizes required to contain the 2y, 5y, 10y, 20y and 100y ARI design flows is provided in Appendix E. This analysis was undertaken by the DRAINS software and prior to using the results the user should be familiar with the limitations of this approach.

DRAINS does not upgrade box culverts and for this reason small box culverts (approximately $1m^2$ or less) were converted to pipes in order to be included in the upgrading process. Large box culverts have not been included in the upgrading process. Also in DRAINS it is generally assumed that overland flow from an upstream pit does not split and all the flow reaches the same downstream pit. This is not necessarily correct and should be investigated prior to the use of the results.

7.6. Flood Data Upstream of Centenary Drive

The 2009 Sydney Water Flood Study (Reference 1) only provided design flood data for the Cooks River downstream of Centenary Drive (within Strathfield Golf Course). As part of this study design flood data were extended to the Strathfield LGA boundary at the upstream end of Strathfield Golf Course (Figure 2). The results of this extension are provided in Appendix F.

8. ACKNOWLEDGEMENTS

This study undertaken by WMAwater was funded by Strathfield Municipal Council and the State Government. The assistance of the following in providing data and guidance to the study is gratefully acknowledged.

- Department of Environment, Climate Change and Water,
- Strathfield Municipal Council,
- NSW State Government,
- Residents of the Cooks River and Coxs Creek catchment.

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19 NSW Department of Environment and Climate Change (DECC)

Floodplain Risk Management Guidelines – Practical Consideration of Climate Change

October 2007

Figures

FIGURE 1

LOCALITY PLAN

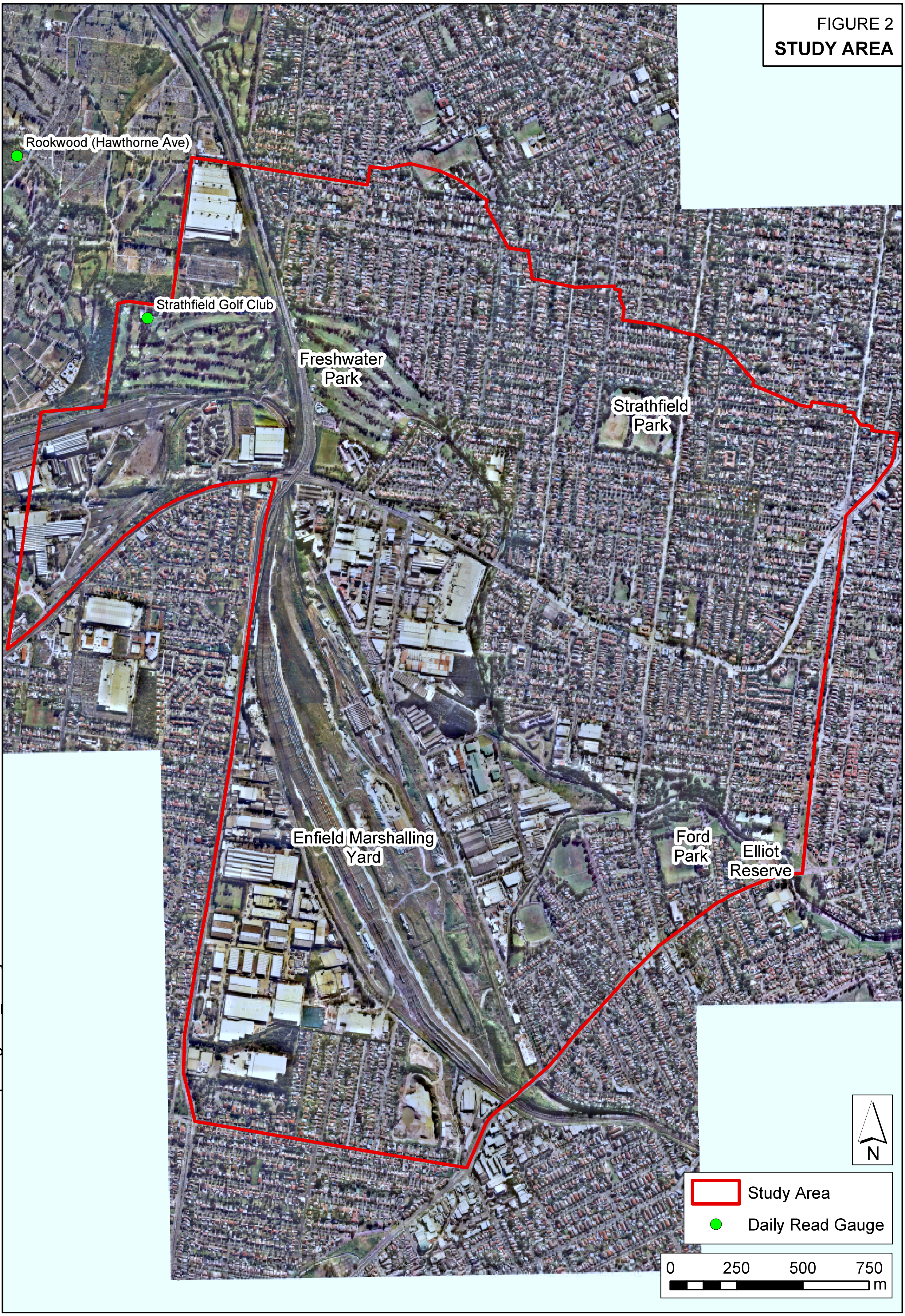
FIGURE 2
STUDY AREA
Rookwood (Hawthorne Ave)
Strathfield Golf Club
Freshwater Park
Strathfield Park
Enfield Marshalling Yard
Ford Park
Elliot Reserve
N
Study Area
Daily Read Gauge
0
250
500
750
m
J:\Jobs\29034\Arcview\Arcmaps\Figure2_StudyArea.mxd

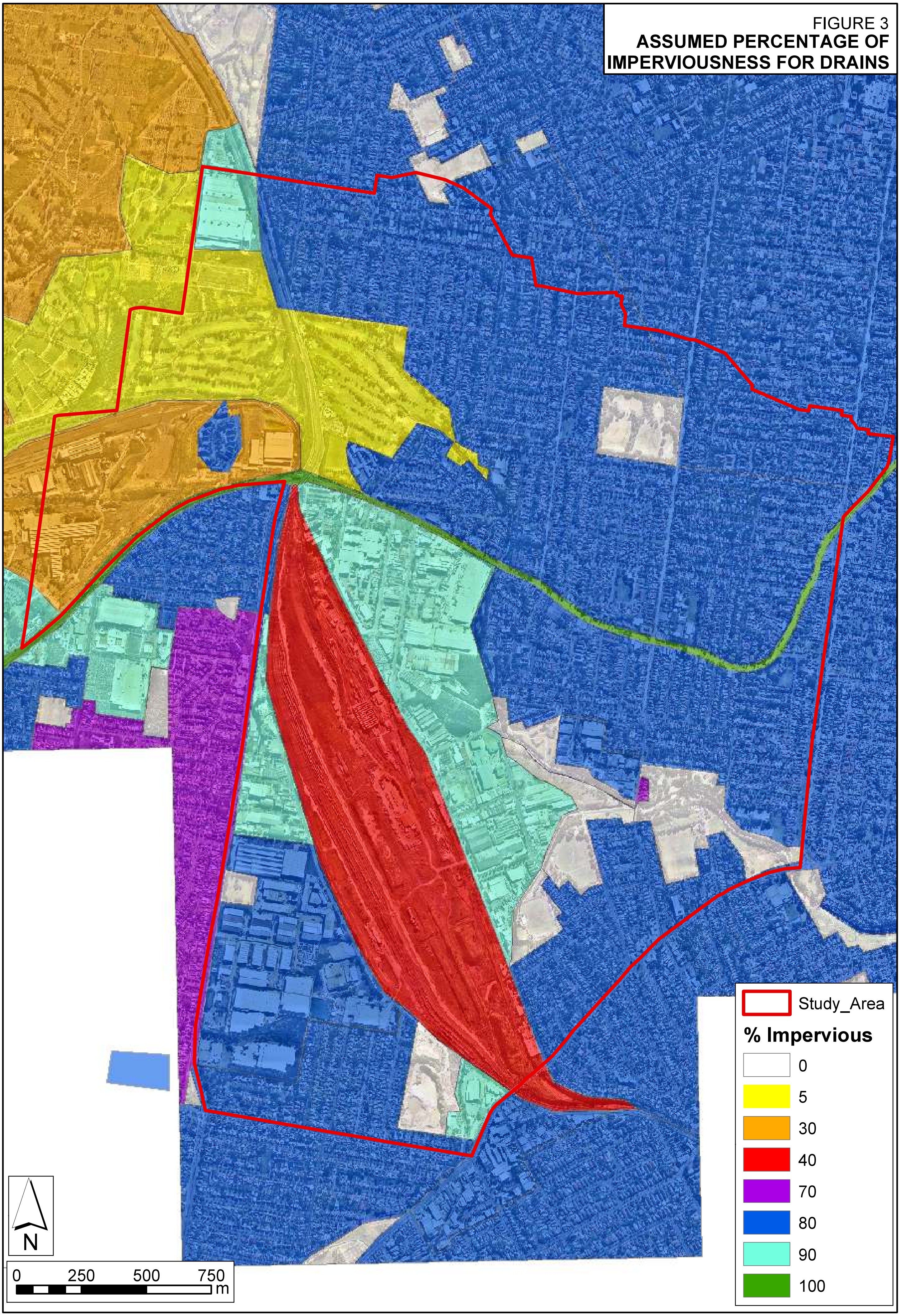

FIGURE 3
ASSUMED PERCENTAGE OF IMPERVIOUSNESS FOR DRAINS

J:\Jobs\29034\Arcview\Arcmaps\Figure3_Imperviousness.mxd

FIGURE 4
HISTORICAL FLOODING

NOTE: This information was obtained from previous flood studies and does not necessarily reflect an accurate picture of the extent or magnitude of the existing flood problem. In places, data may be missing or the identified problem subsequently resolved.

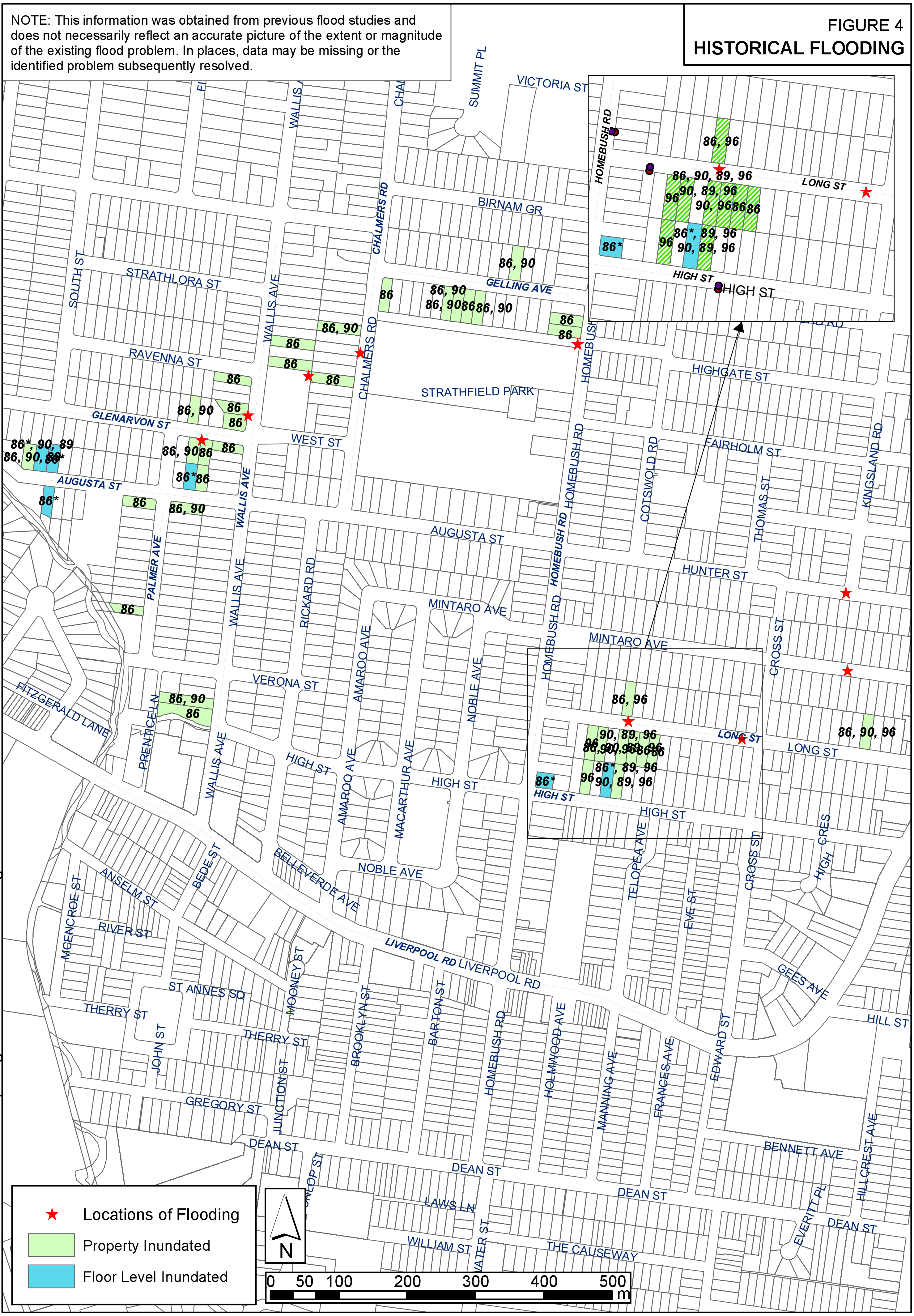

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FIGURE 5a

LOCALITIES WHERE QUESTIONNAIRE DISTRIBUTED

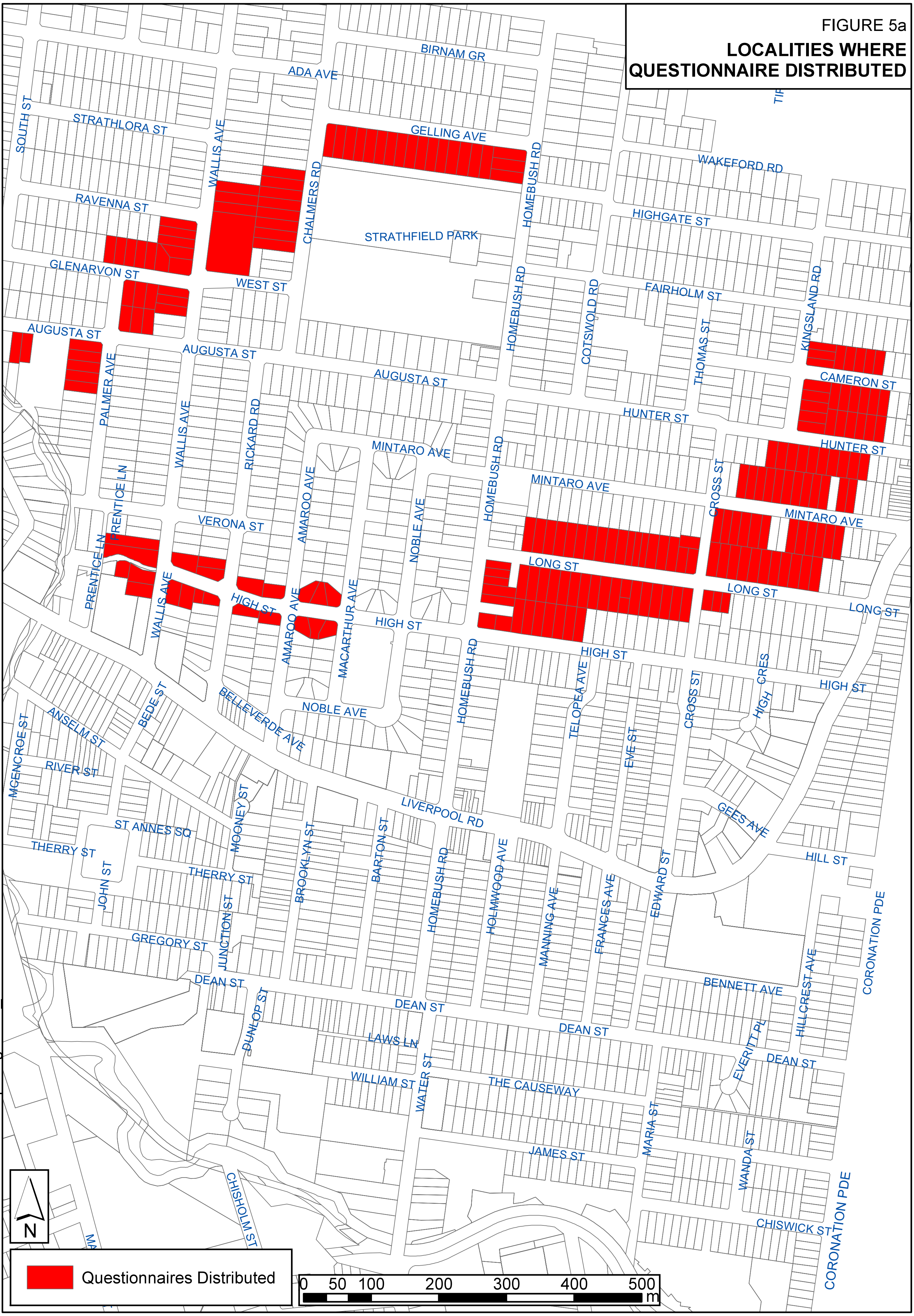

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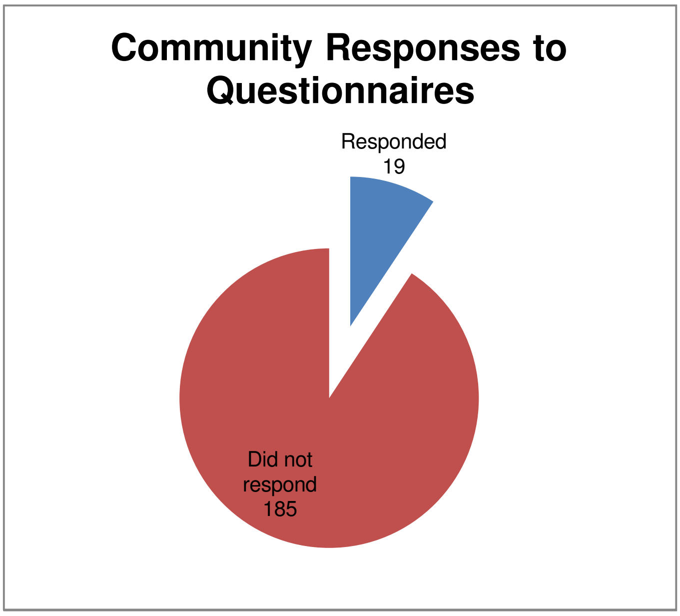
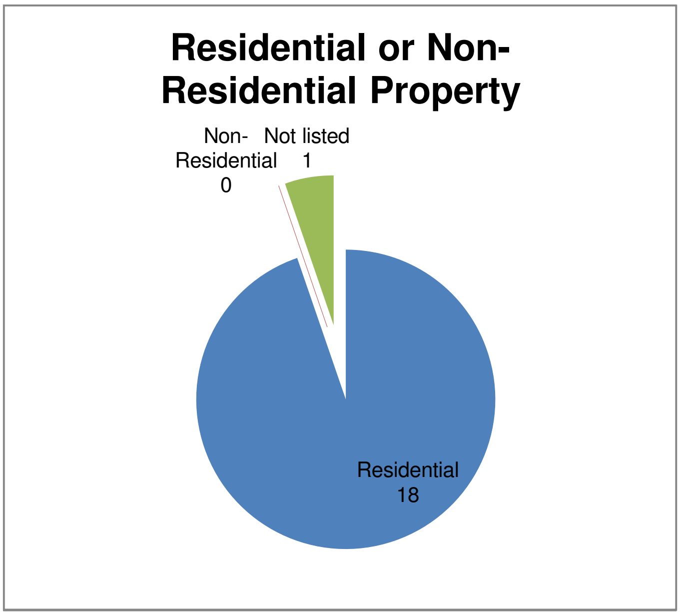
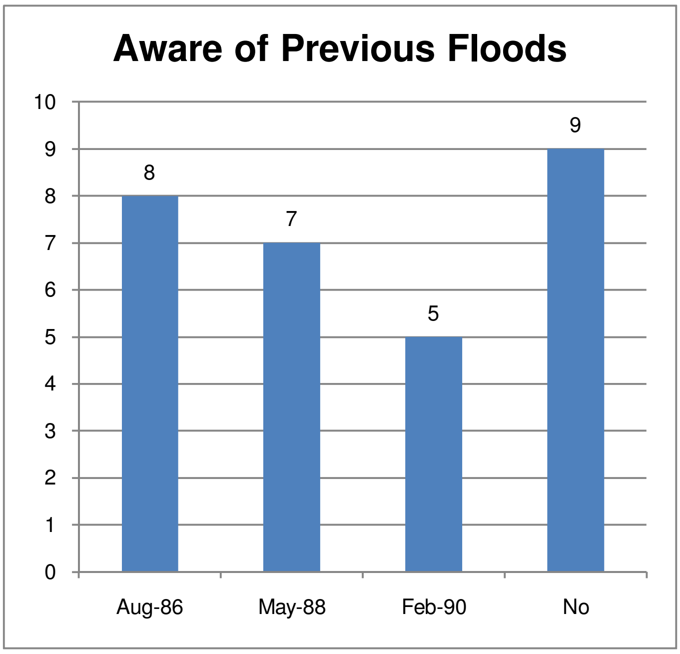
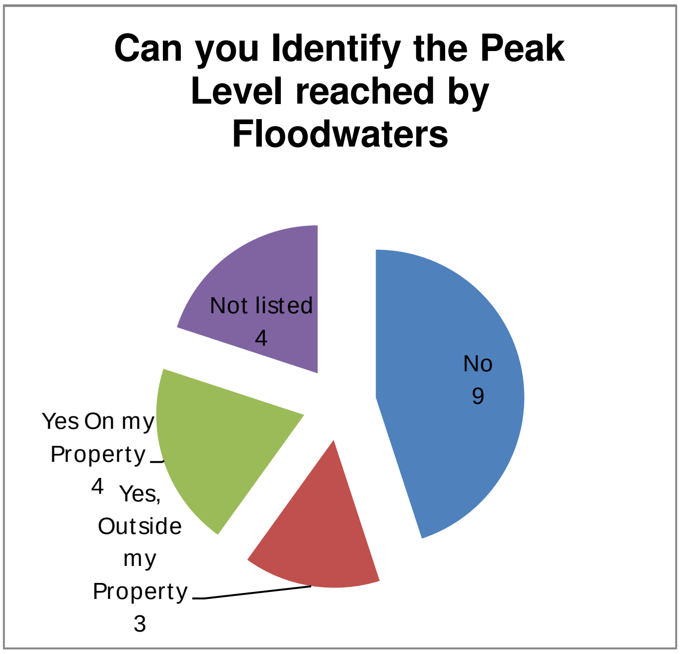
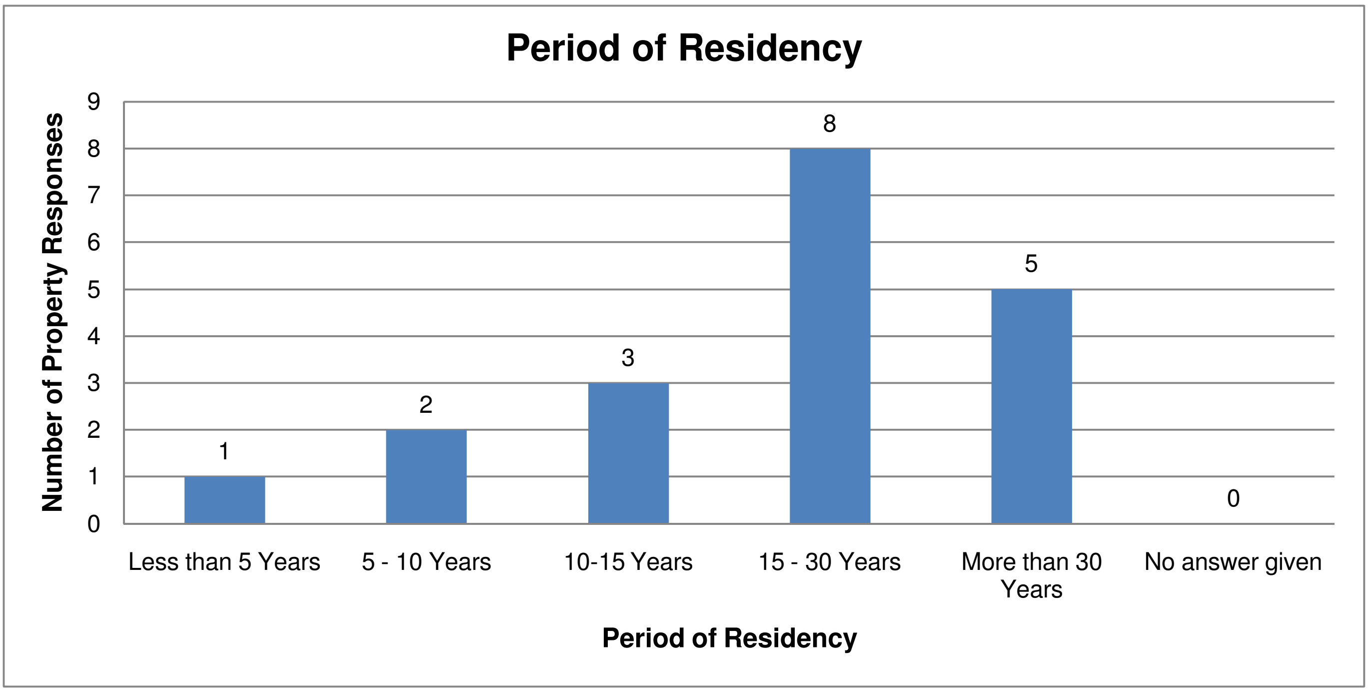
FIGURE 5b
RESULTS OF QUESTIONNAIRE











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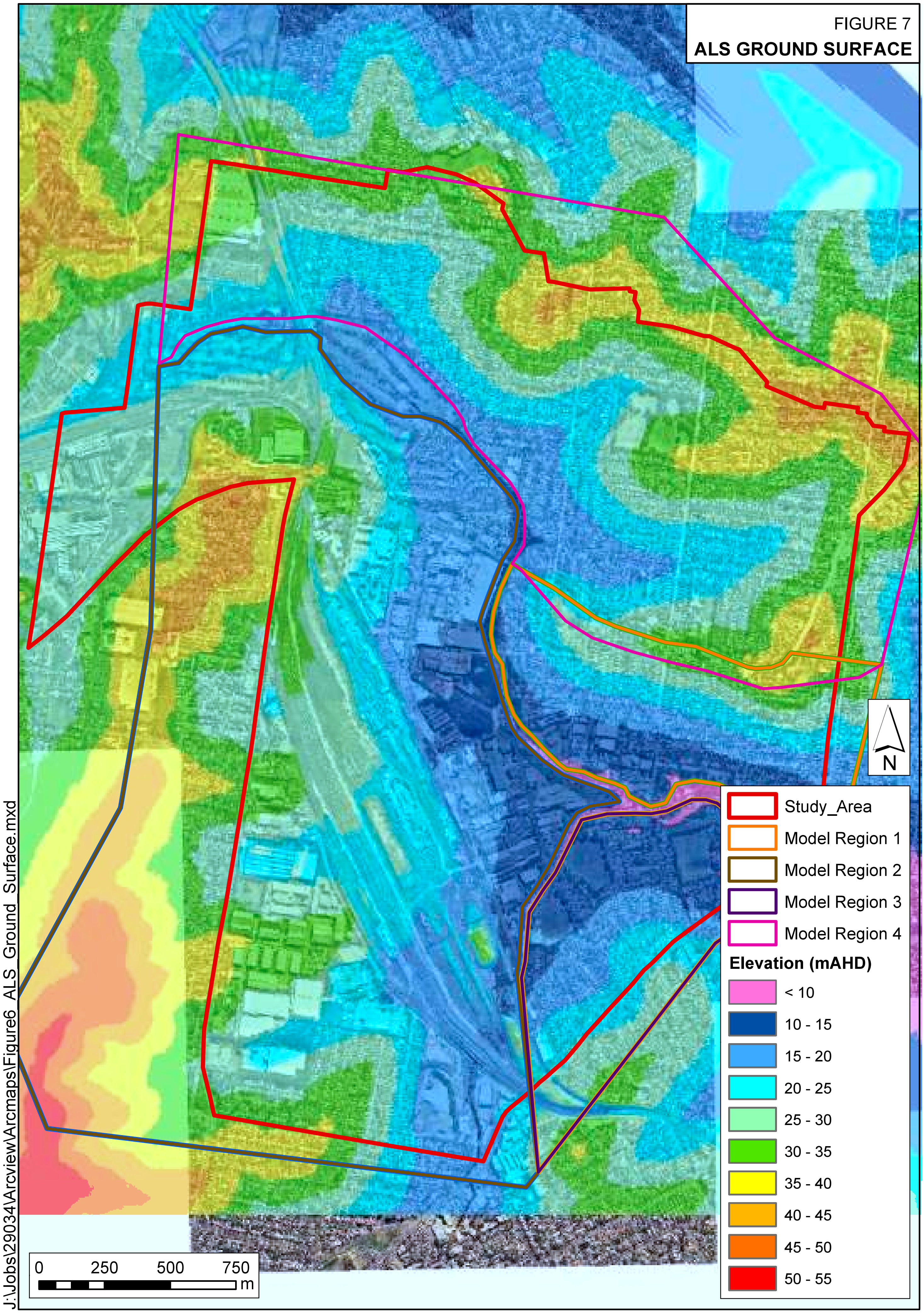
FIGURE 7
ALS GROUND SURFACE
Study_Area
Model Region 1
Model Region 2
Model Region 3
Model Region 4
Elevation (mAHD)
< 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
50 - 55
N
0 250 500 750
m
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FIGURE 8

PIT AND PIPE NETWORK INCLUDED IN DRAINS

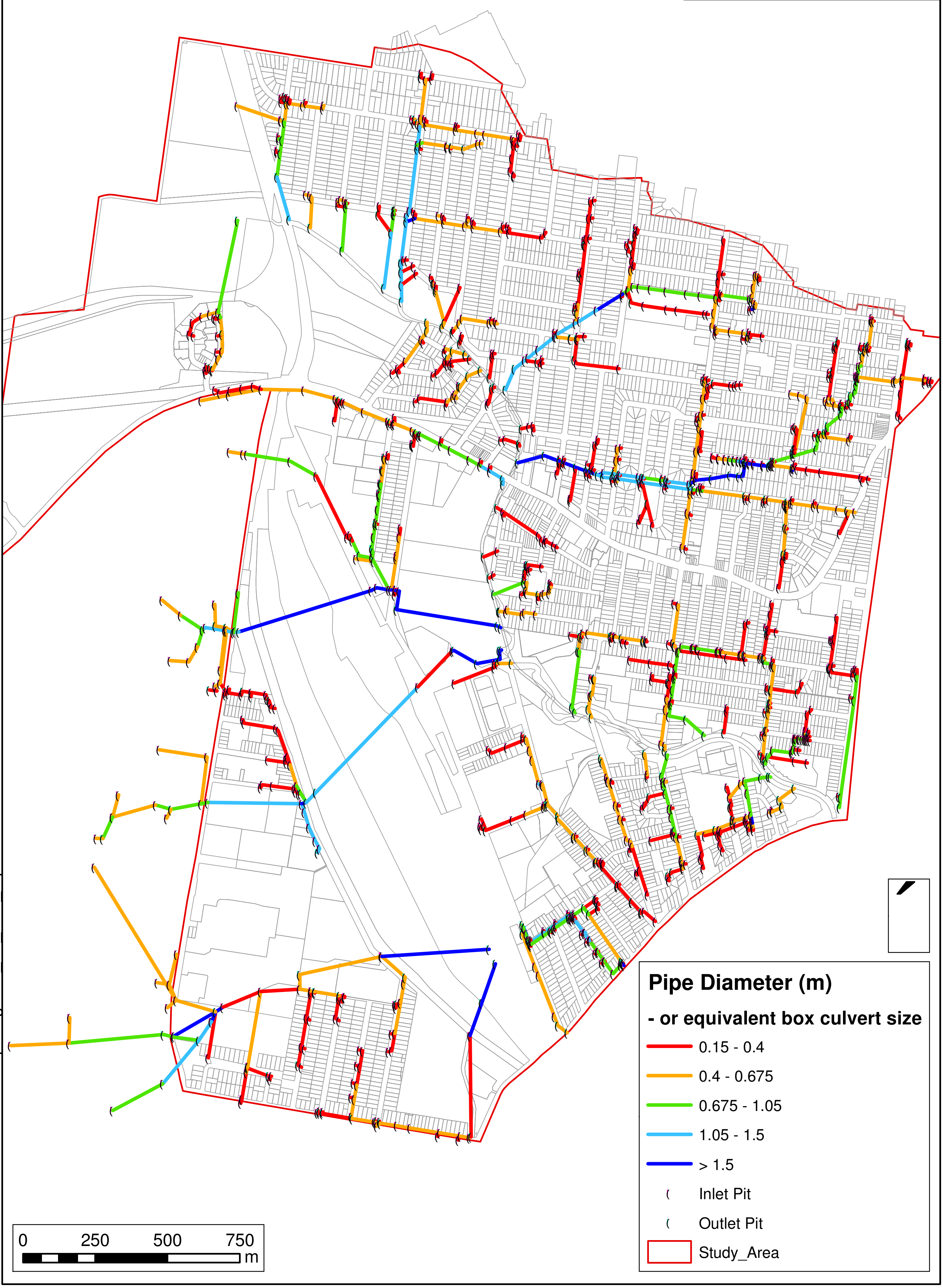

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FIGURE 9
MAINSTREAM FLOODING
COOKS RIVER AND COX CREEK

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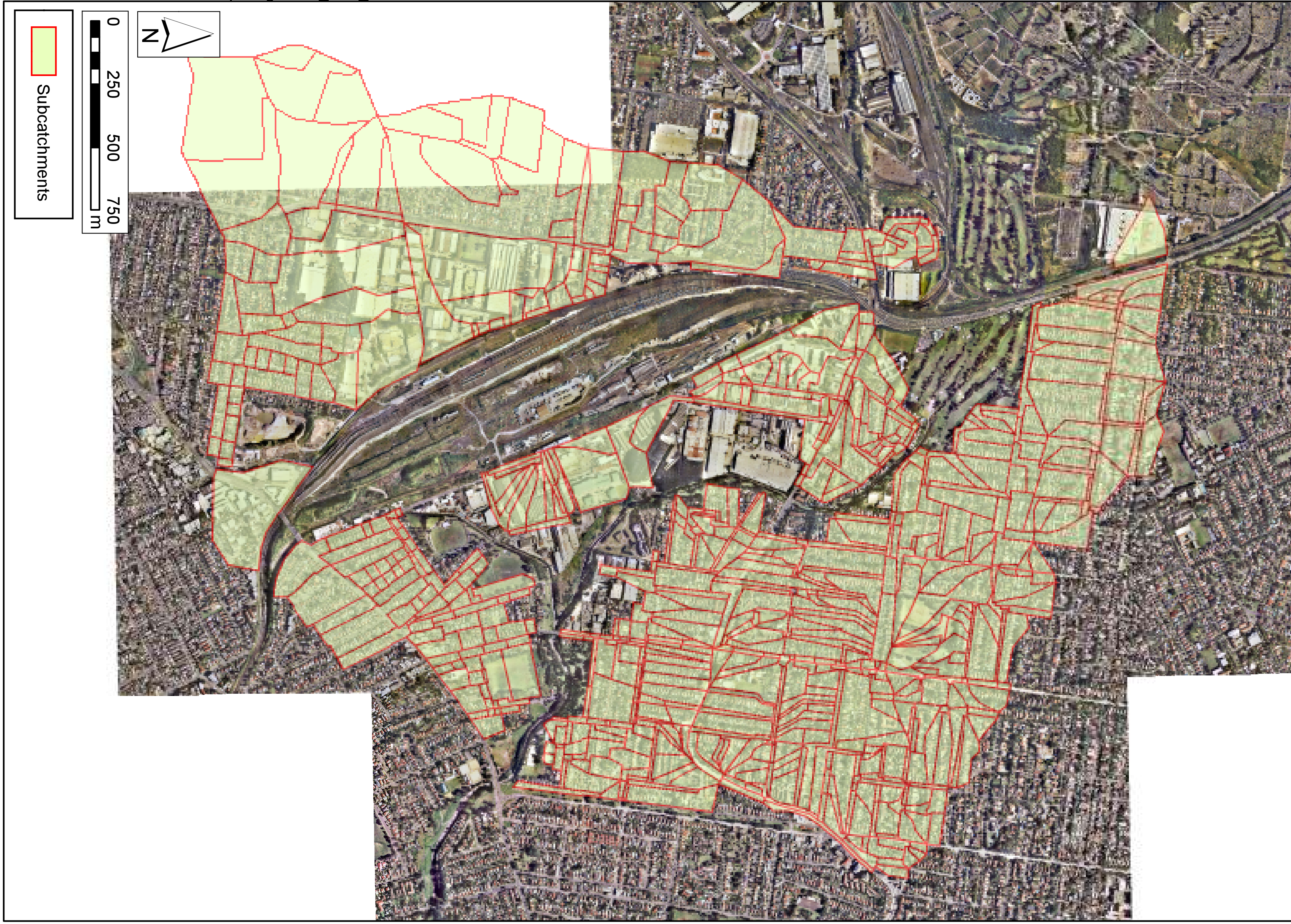

FIGURE 10
SUBCATCHMENT AREAS

FIGURE 11a
MAINSTREAM FLOOD EXTENT
COOKS RIVER FLOOD STUDY
2 YEAR ARI

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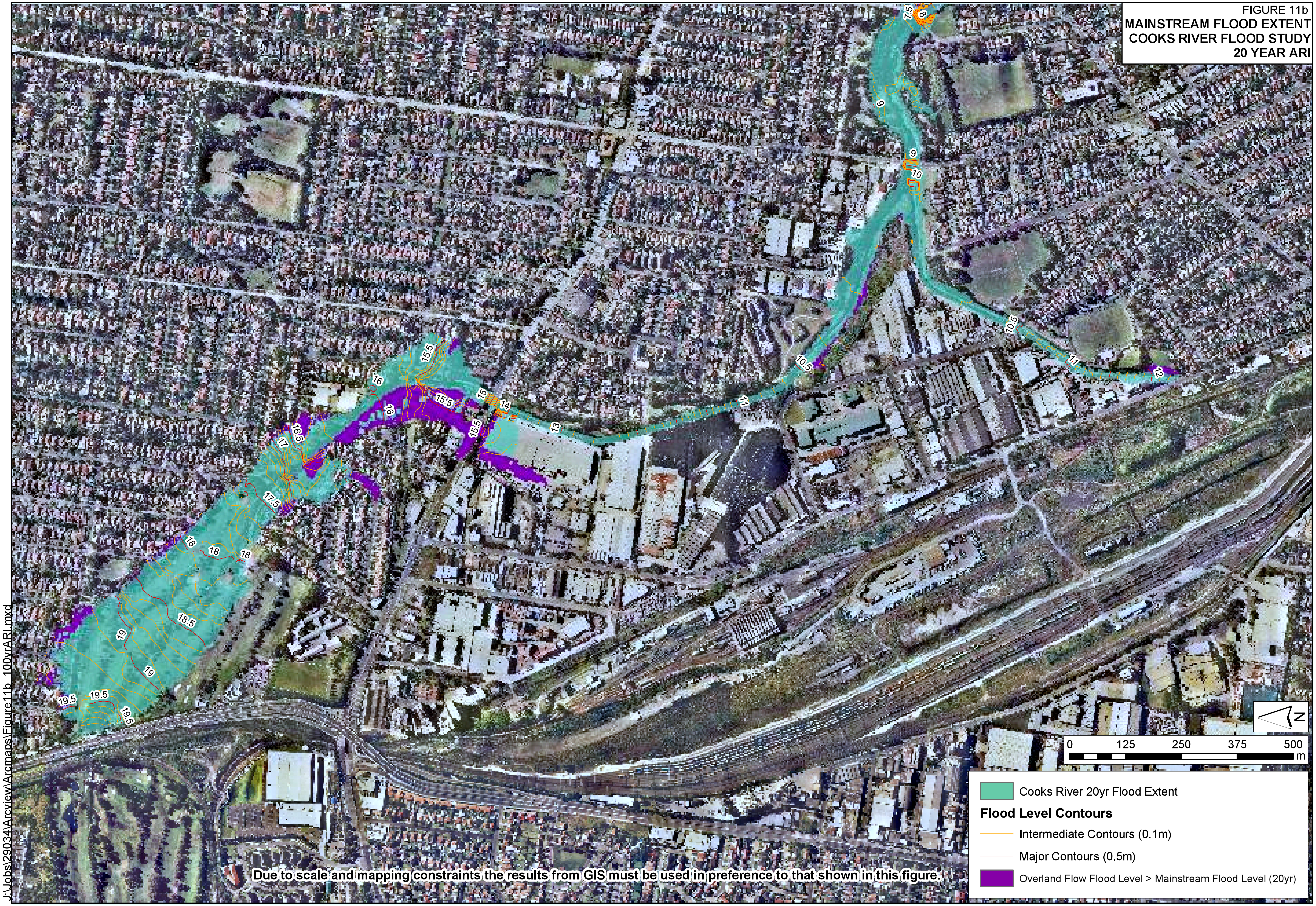

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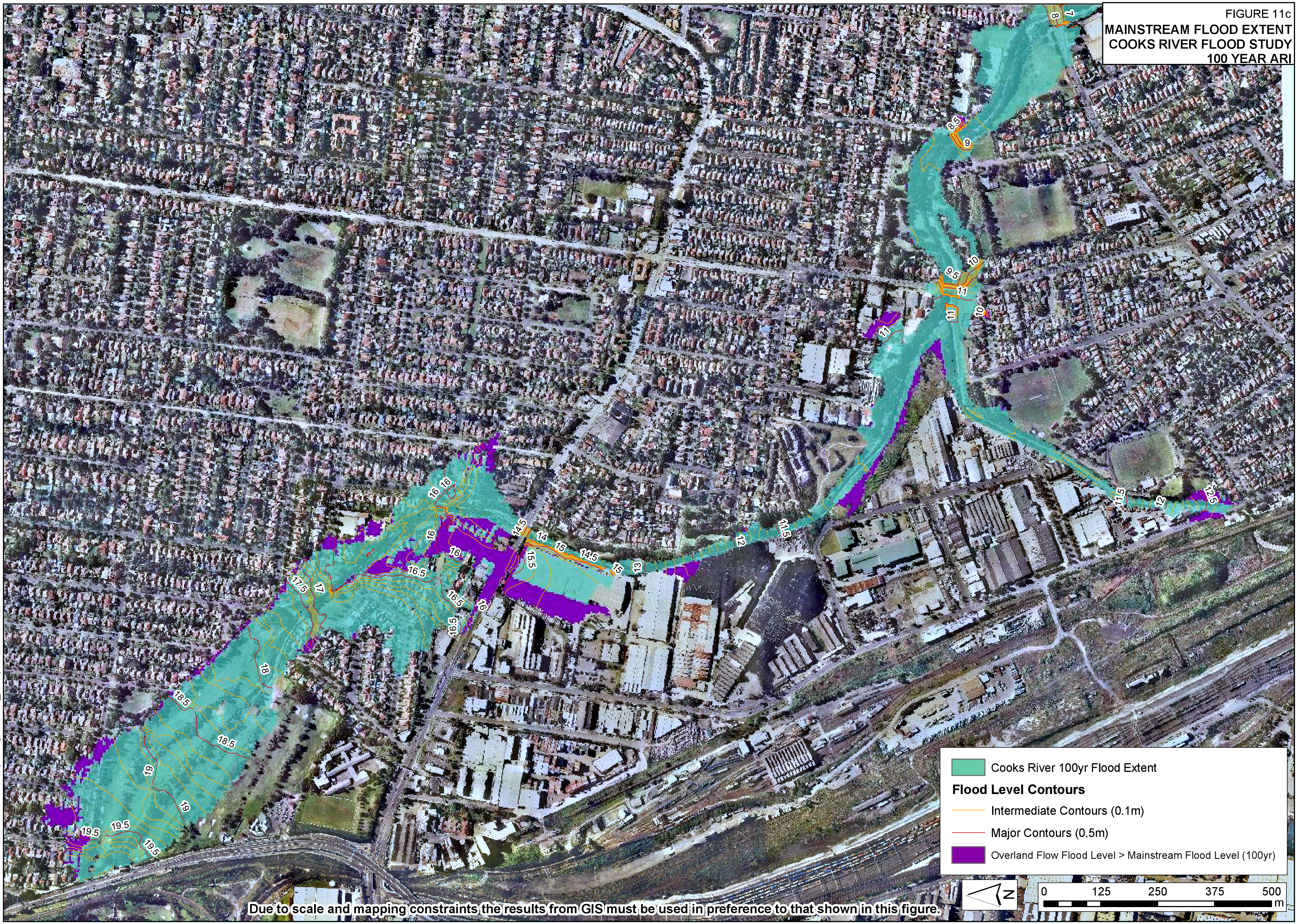

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FIGURE 11d
MAINSTREAM FLOOD EXTENT
COOKS RIVER FLOOD STUDY
PMF

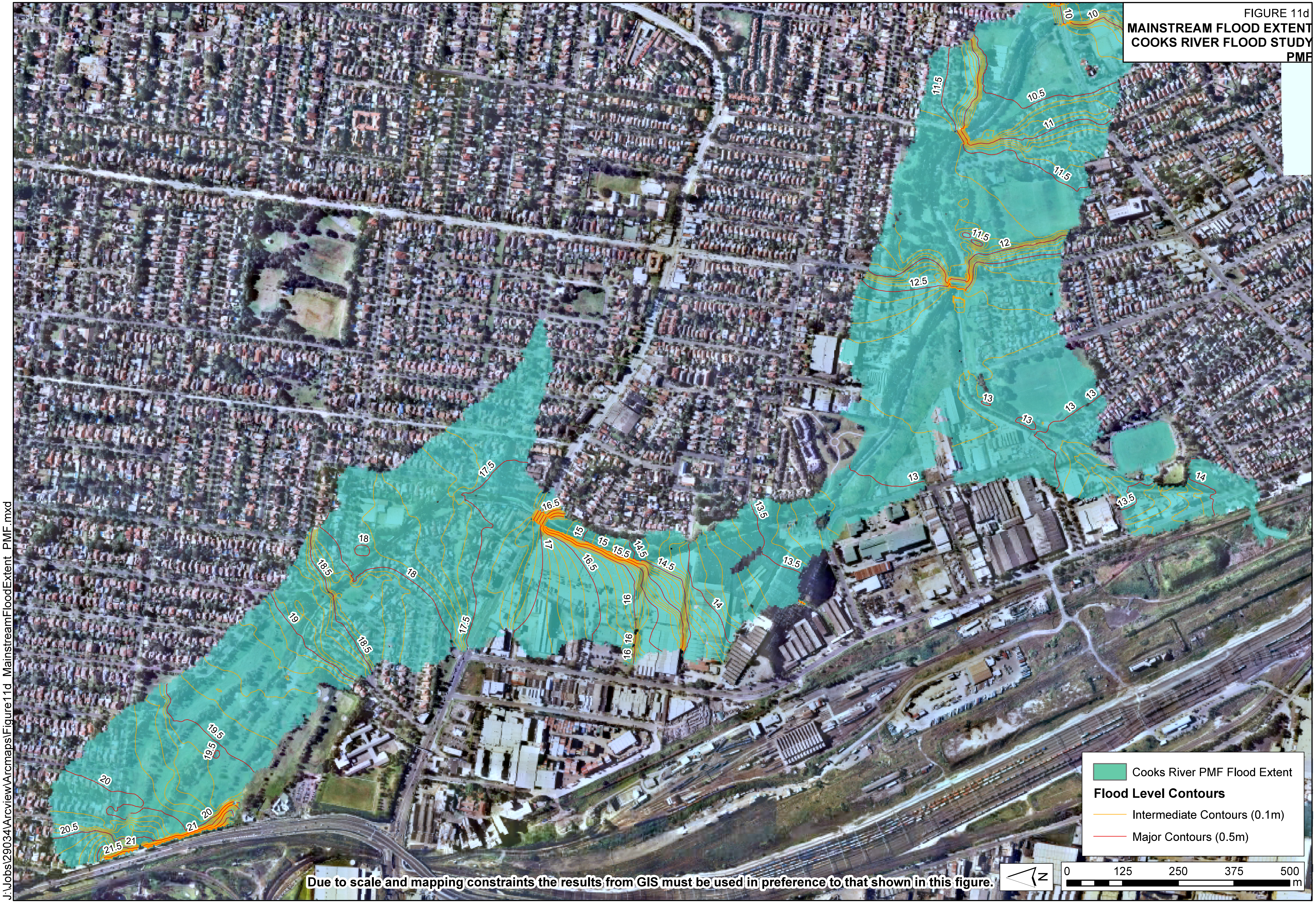

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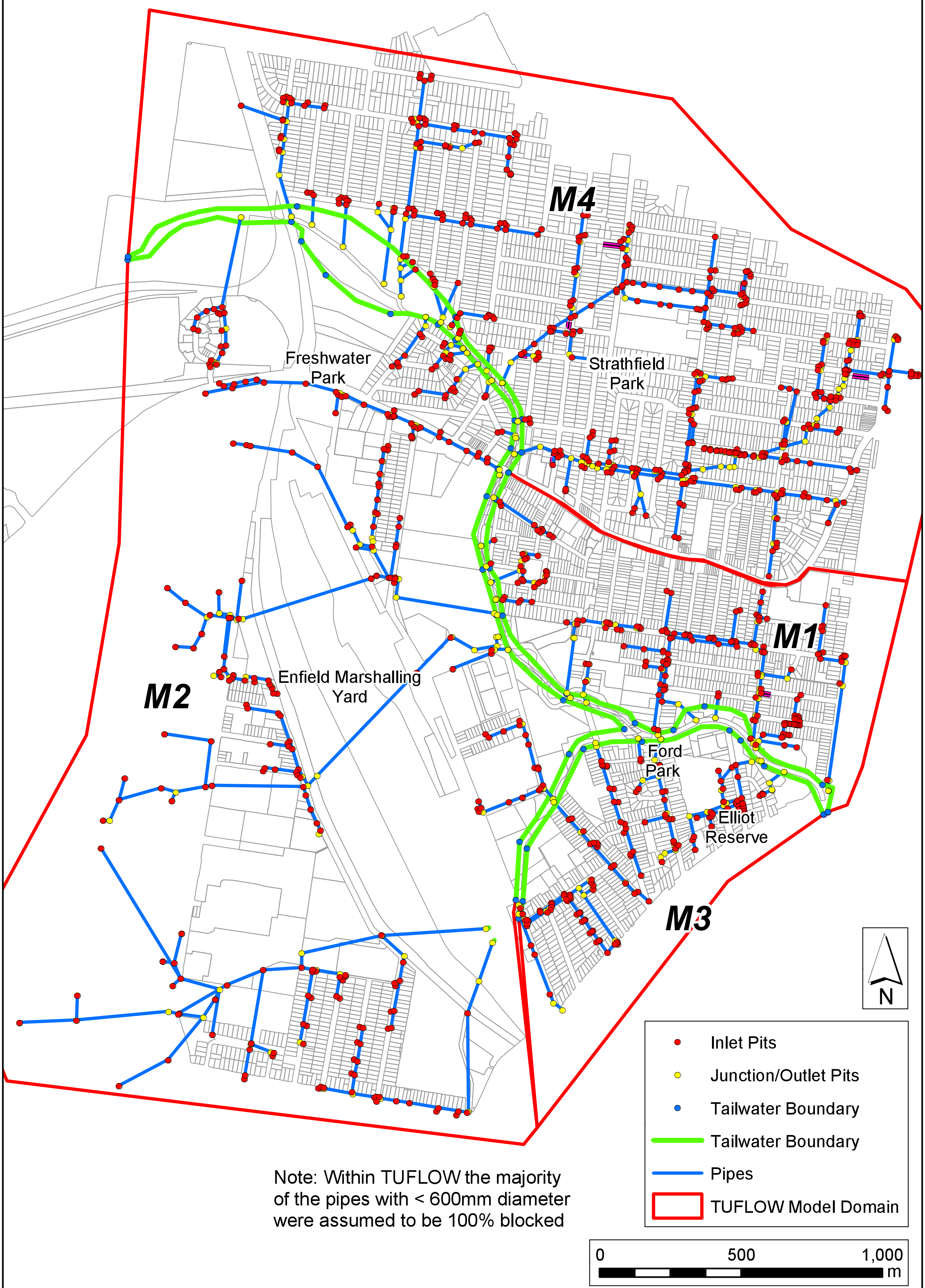
FIGURE 12A

TUFLOW MODEL LAYOUT



Note: Within TUFLOW the majority of the pipes with < 600mm diameter were assumed to be 100% blocked

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FIGURE 12B

LOCATIONS OF DESIGN FLOOD PROFILES

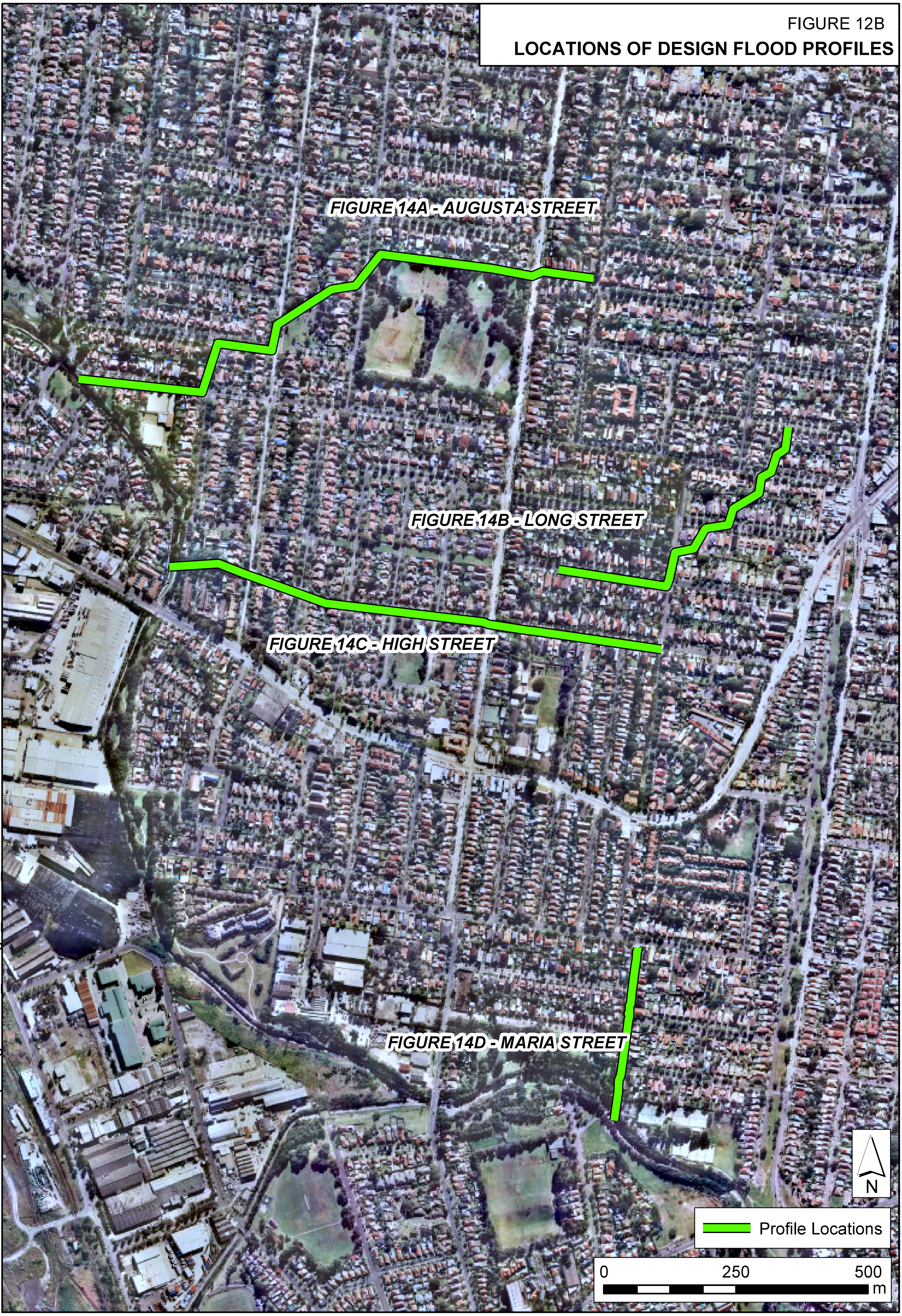

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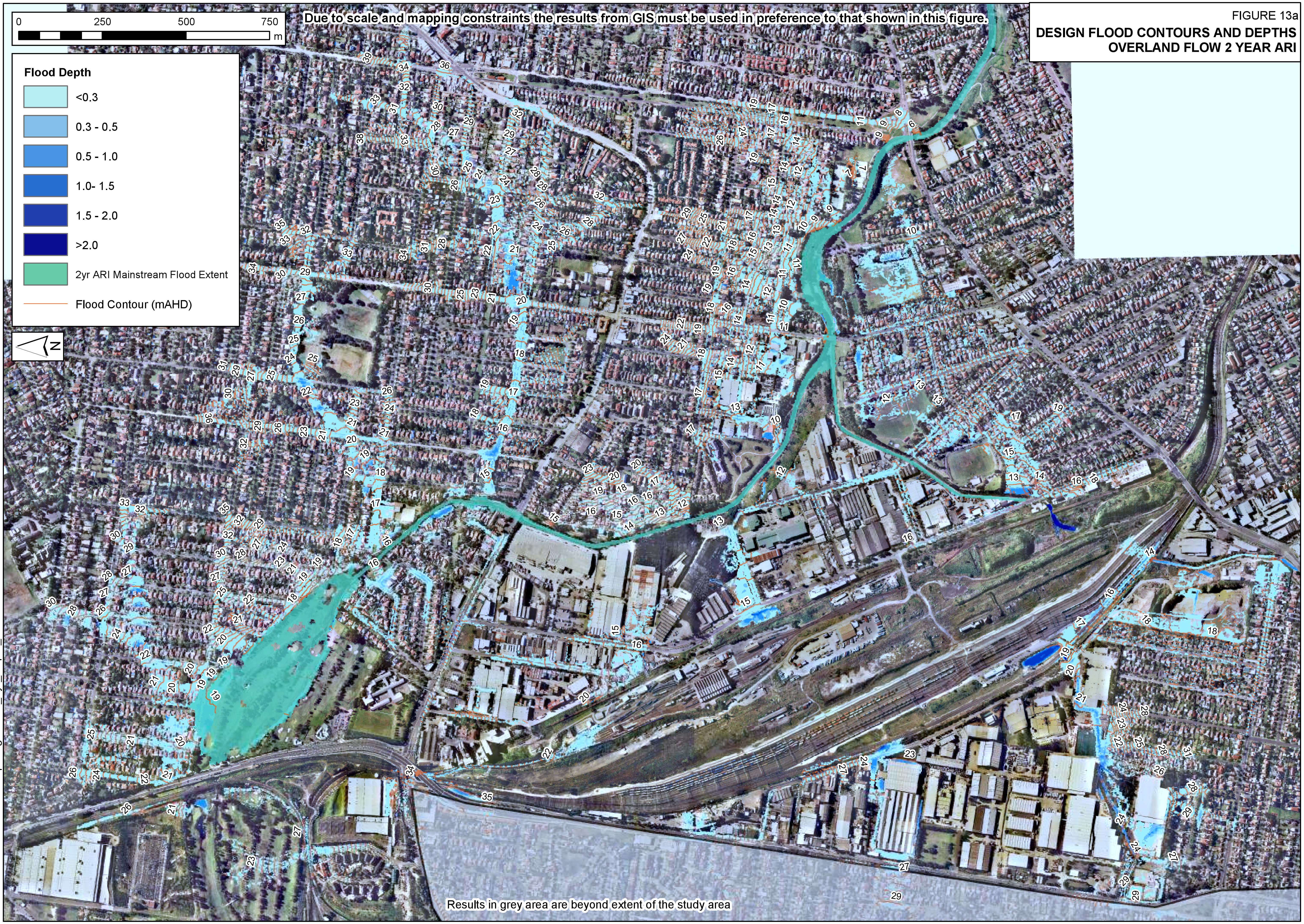
FIGURE 13a
DESIGN FLOOD CONTOURS AND DEPTHS OVERLAND FLOW 2 YEAR ARI



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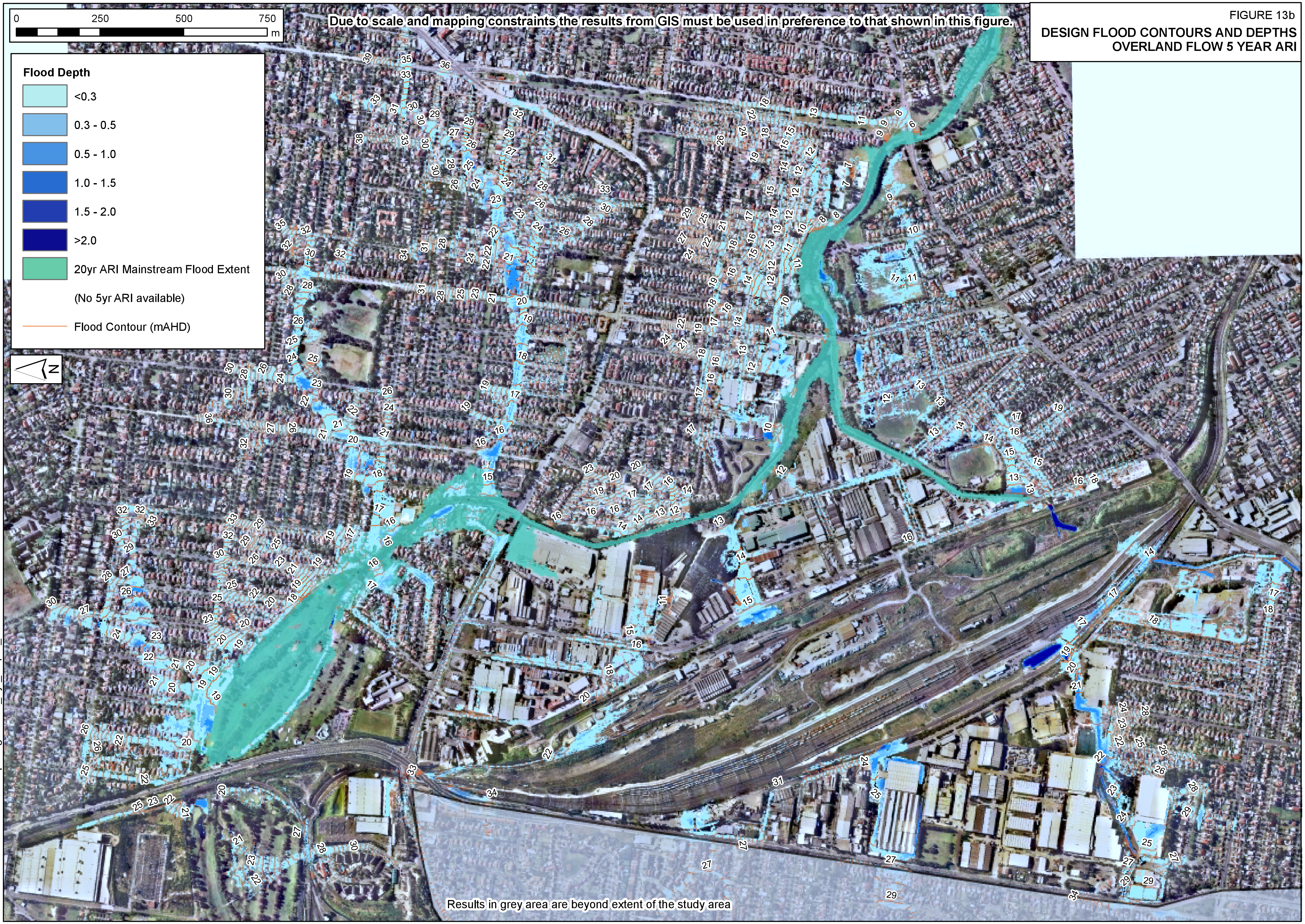

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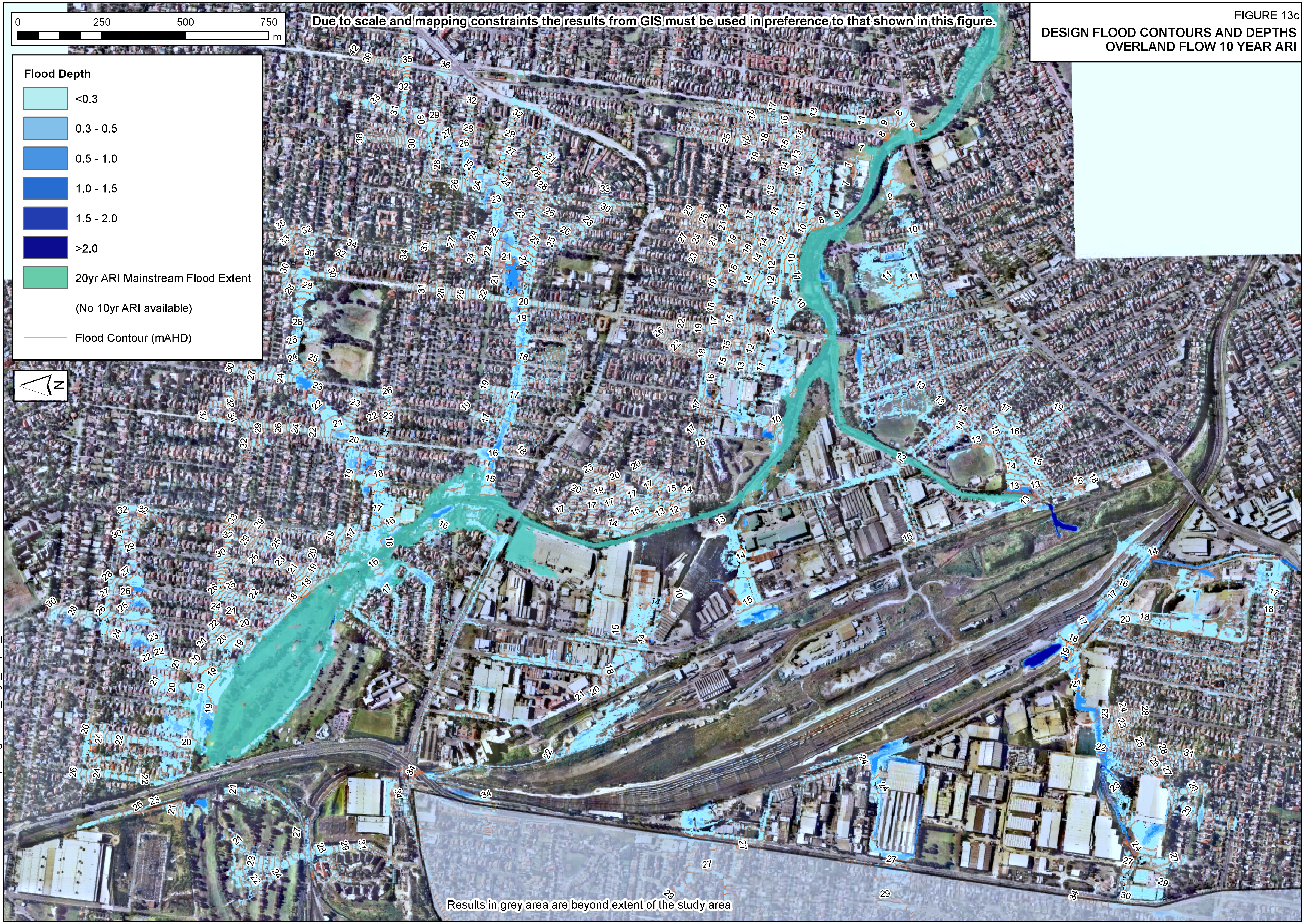

FIGURE 13c
DESIGN FLOOD CONTOURS AND DEPTHS
OVERLAND FLOW 10 YEAR ARI

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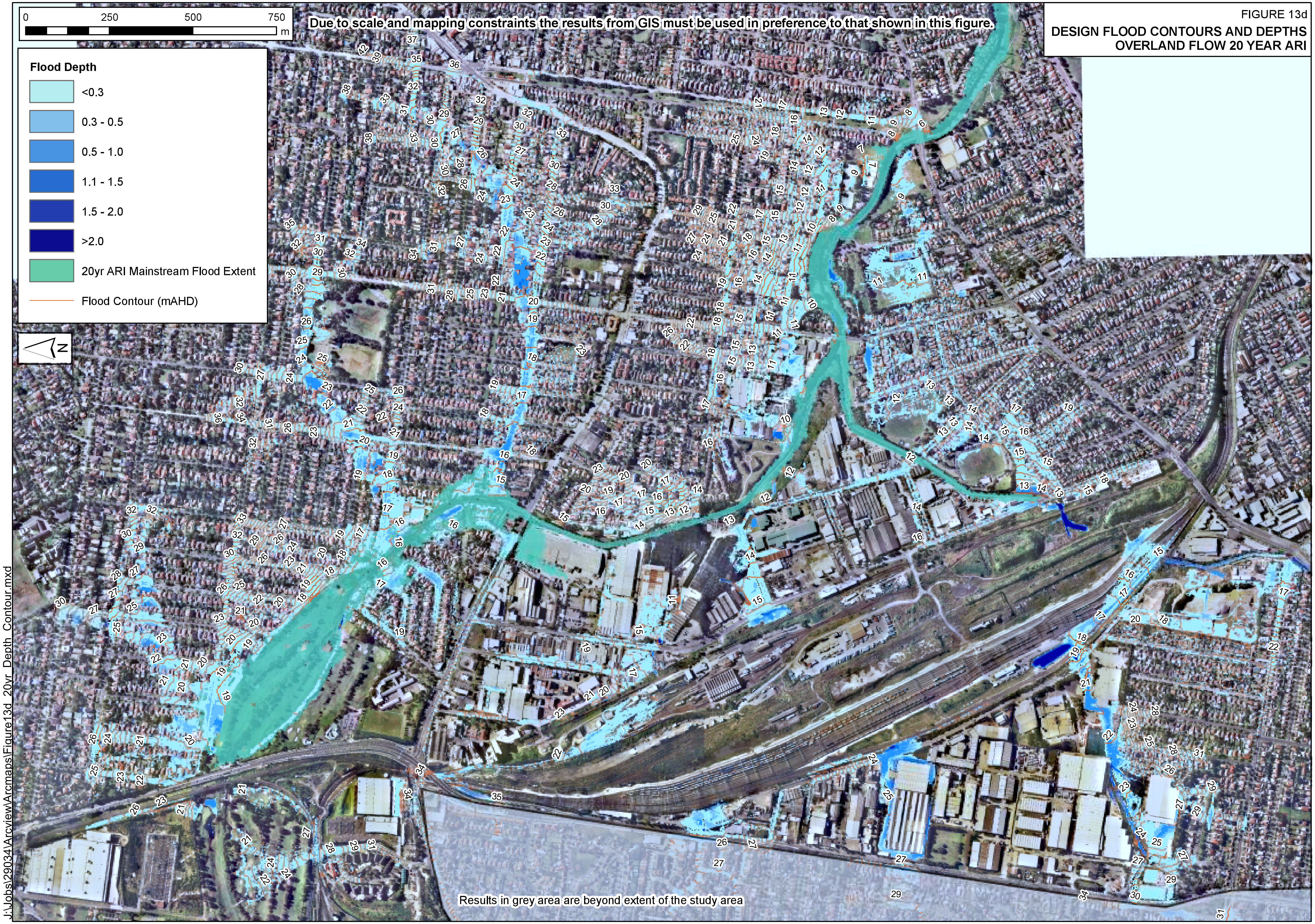

FIGURE 13d
DESIGN FLOOD CONTOURS AND DEPTHS
OVERLAND FLOW 20 YEAR ARI

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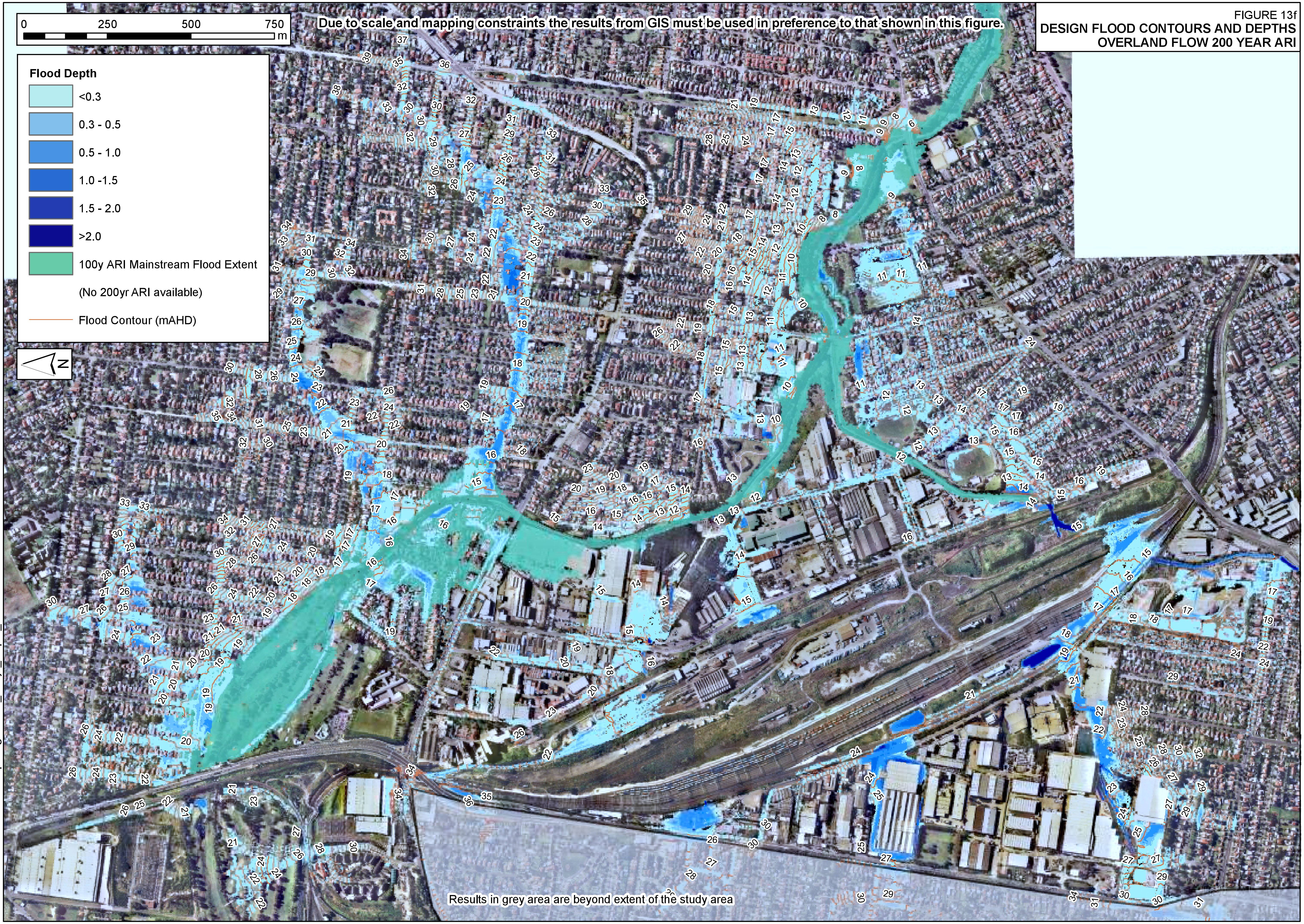
J:\Jobs\29034\Arcview\Arcmaps\Figure13E_100yr_Depth_Contour.mxd

FIGURE 13f
DESIGN FLOOD CONTOURS AND DEPTHS
OVERLAND FLOW 200 YEAR ARI



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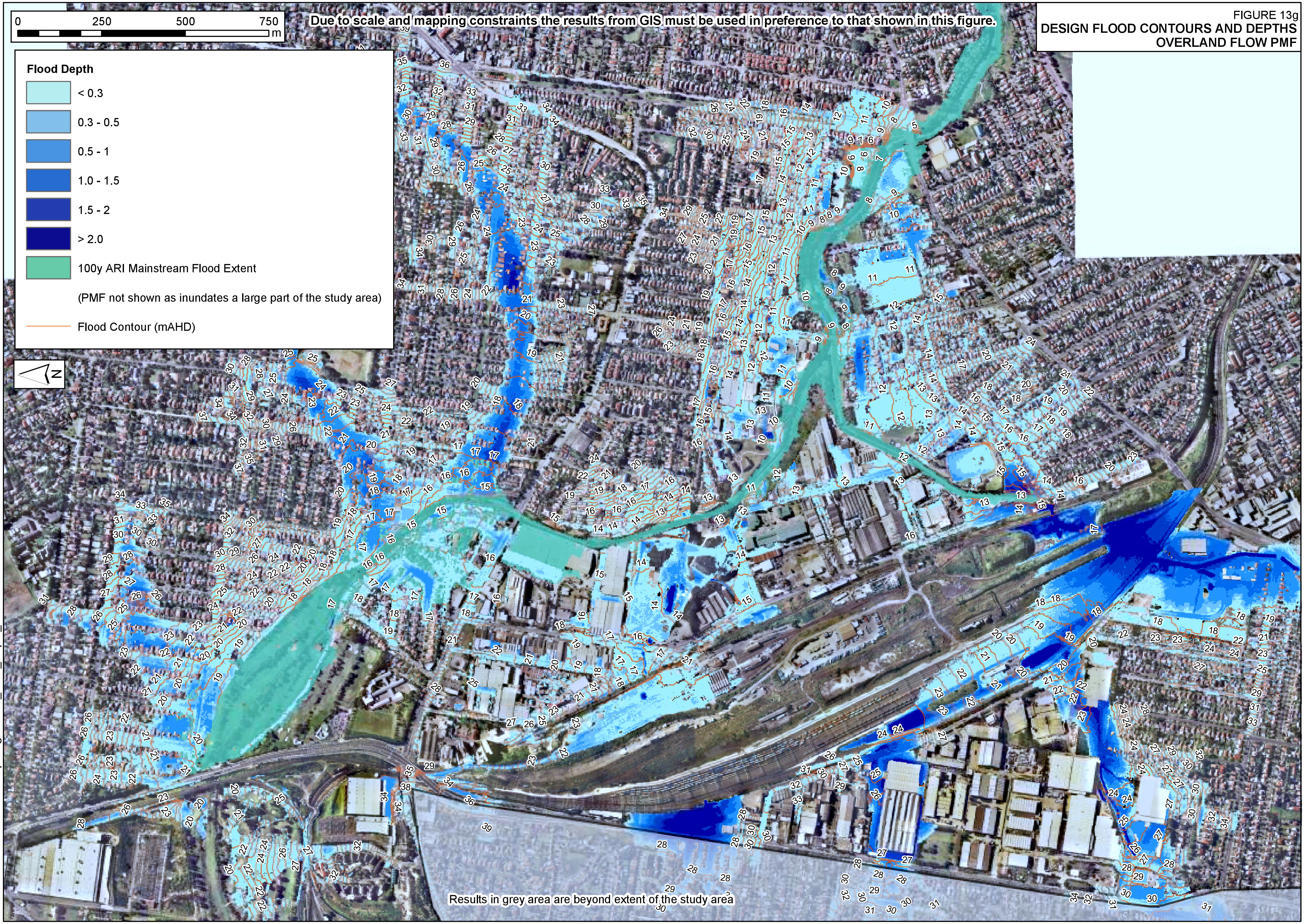

FIGURE 13g
DESIGN FLOOD CONTOURS AND DEPTHS
OVERLAND FLOW PMF

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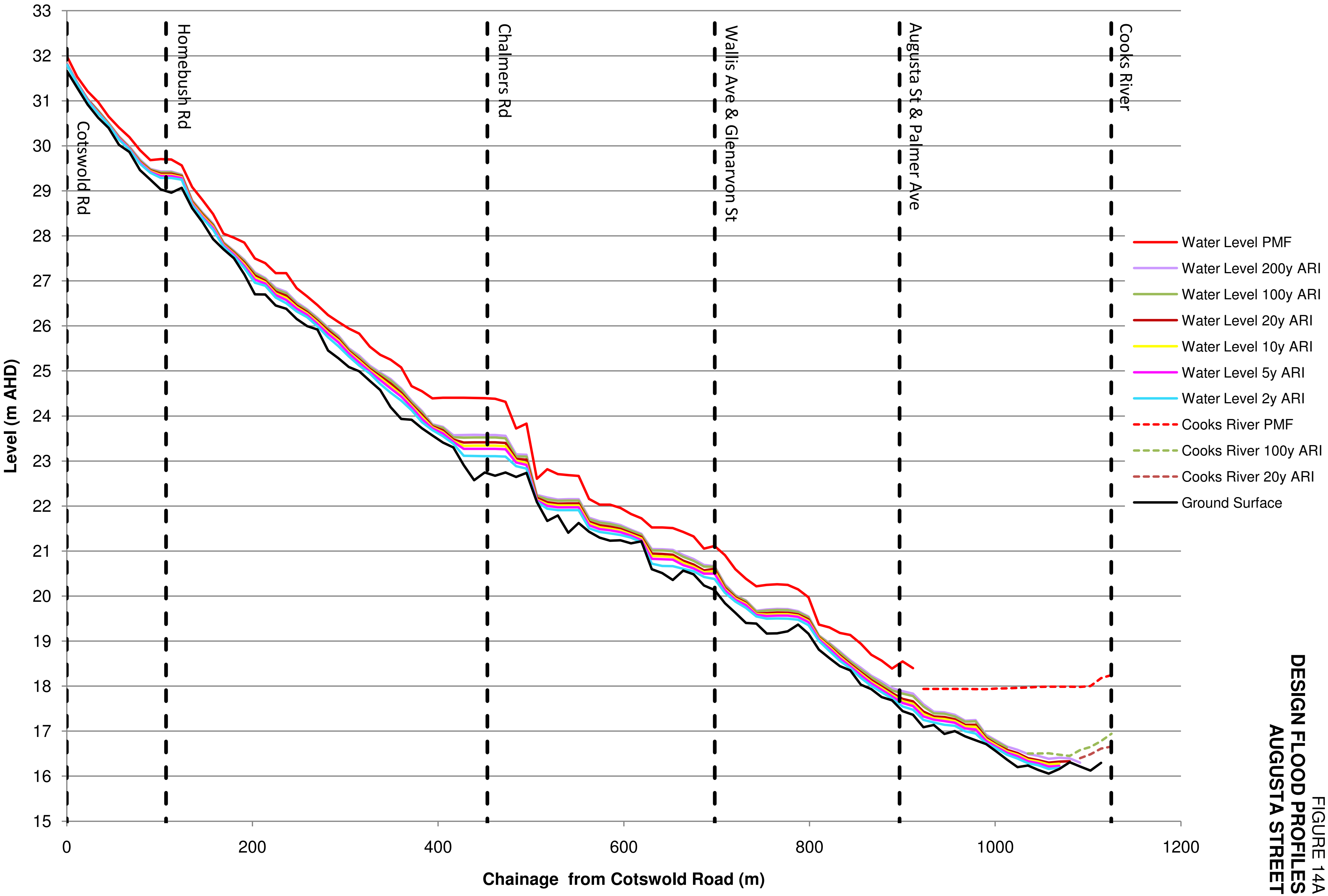


FIGURE 14A
DESIGN FLOOD PROFILES
AUGUSTA STREET

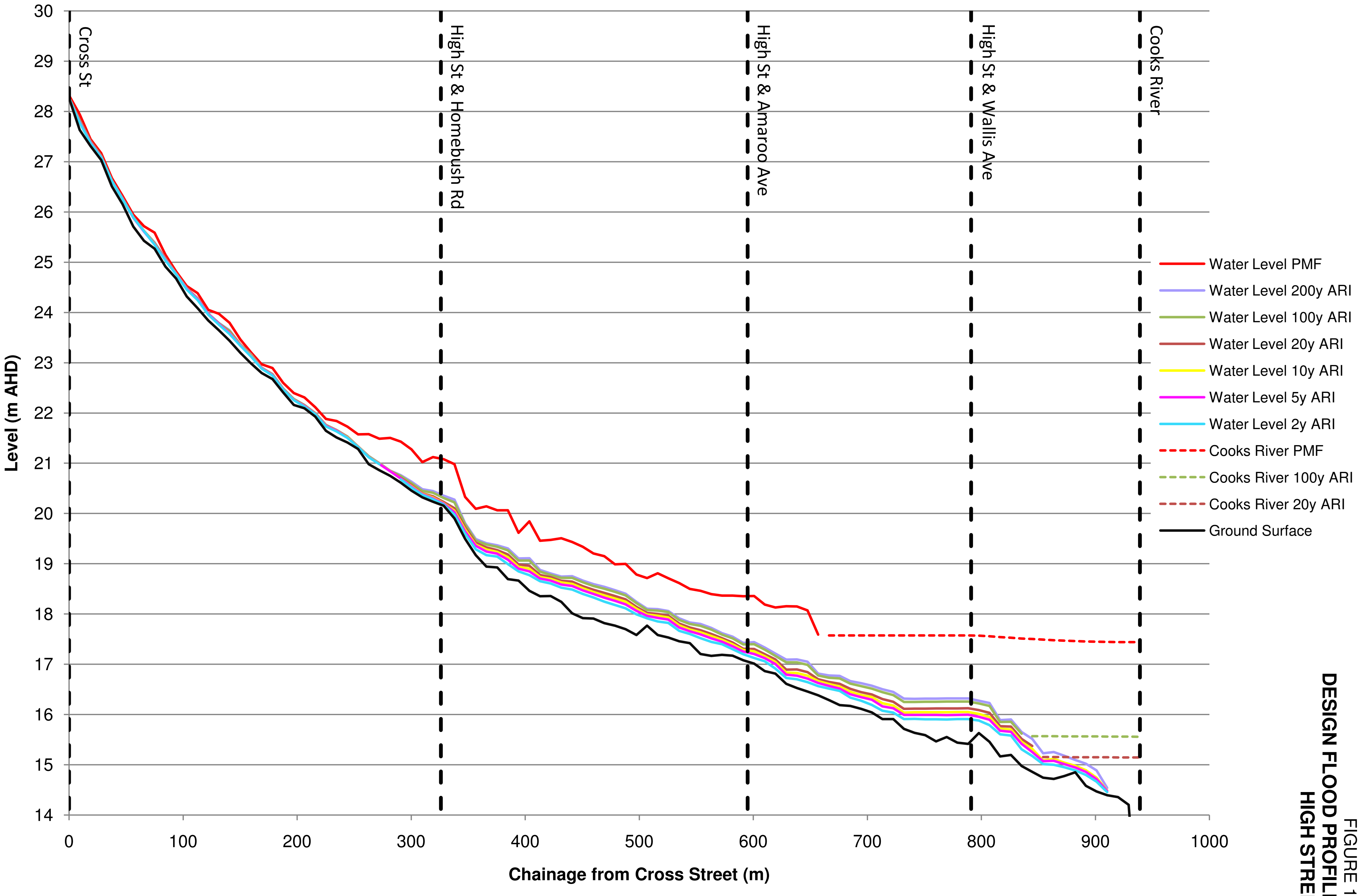


FIGURE 14B
DESIGN FLOOD PROFILES
HIGH STREET

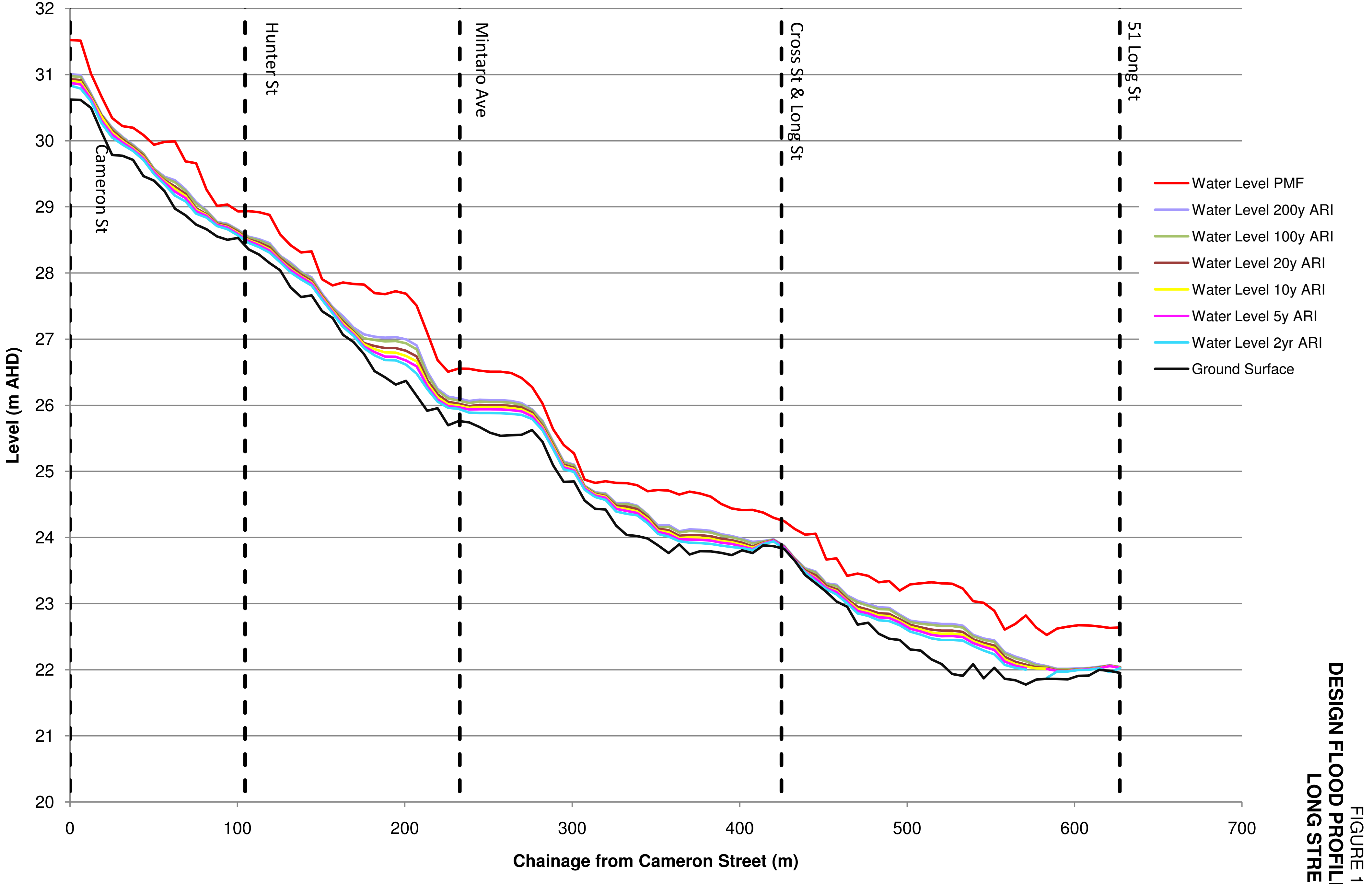


FIGURE 14C
DESIGN FLOOD PROFILES
LONG STREET

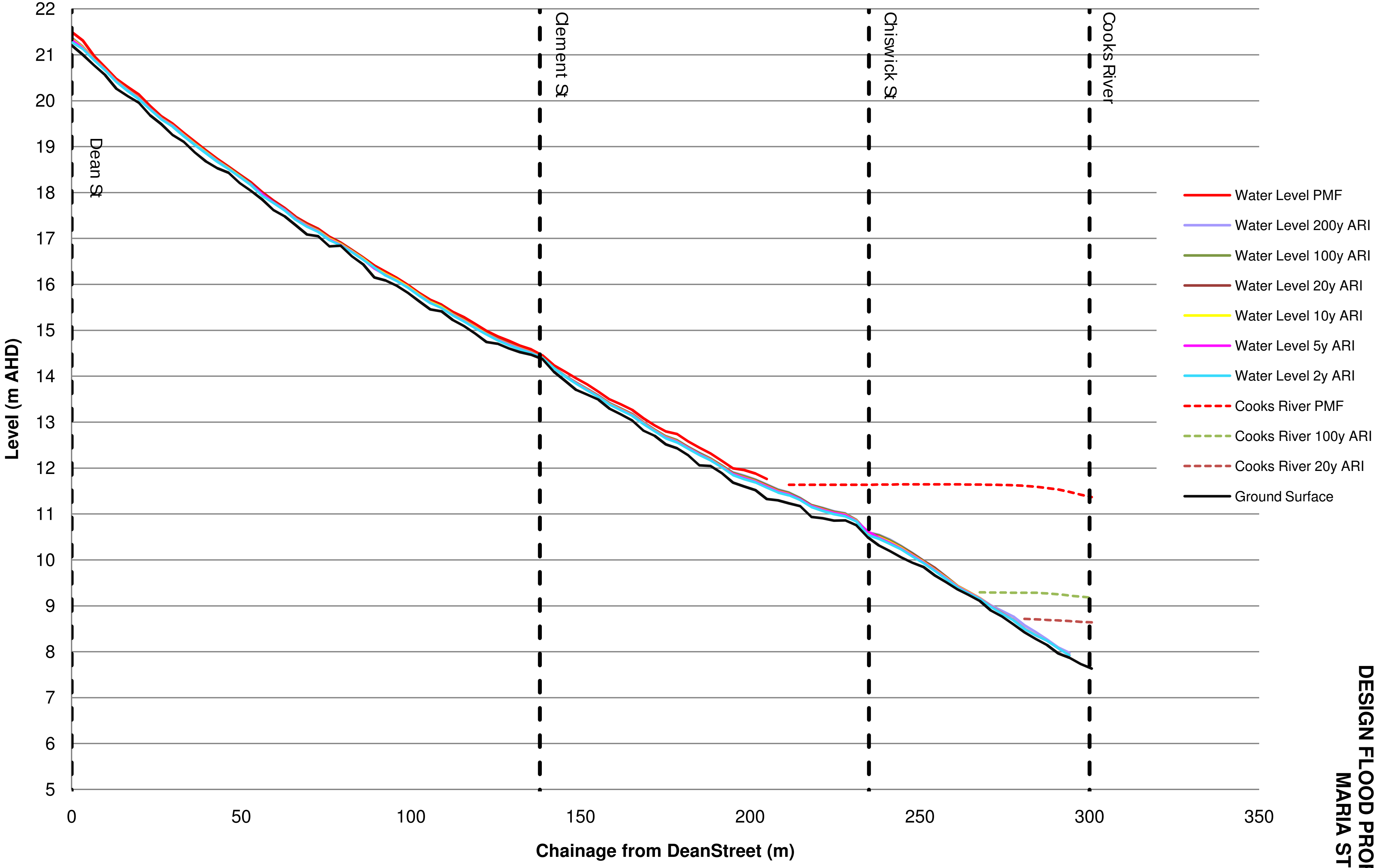
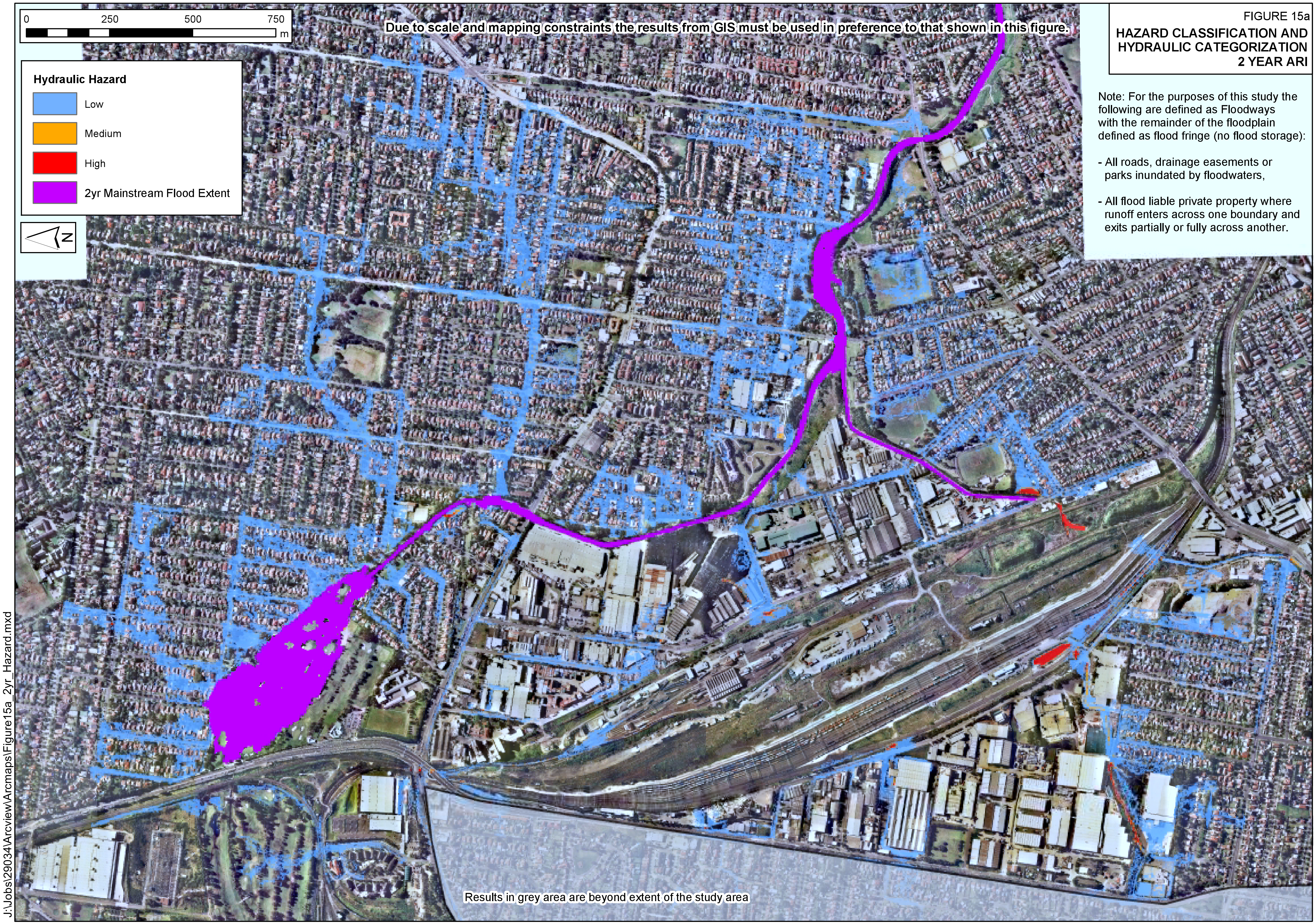


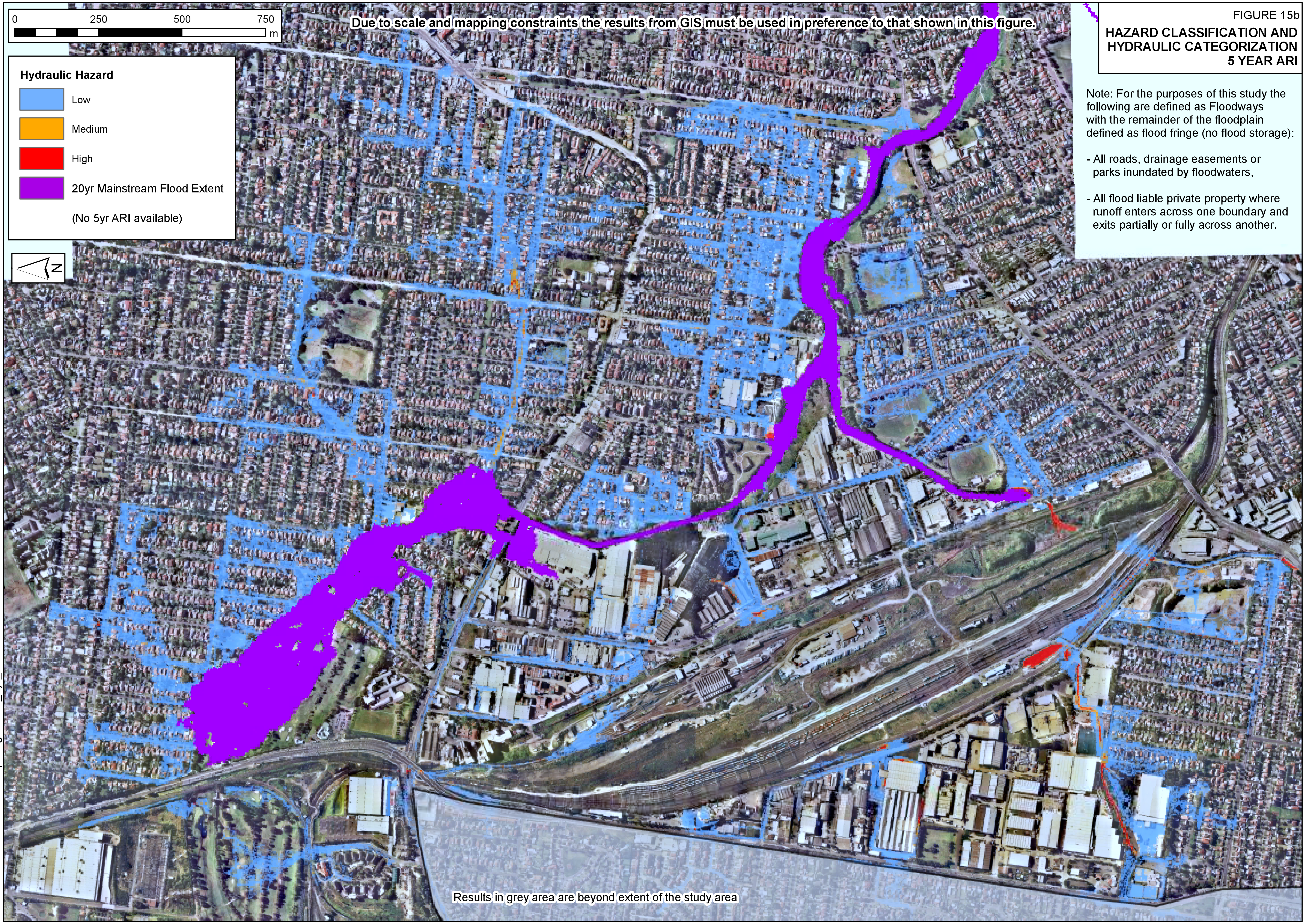
FIGURE 14D

DESIGN FLOOD PROFILES

MARIA STREET



0 250 500 750 m
Due to scale and mapping constraints the results from GIS must be used in preference to that shown in this figure.
FIGURE 15a
HAZARD CLASSIFICATION AND HYDRAULIC CATEGORIZATION 2 YEAR ARI
Note: For the purposes of this study the following are defined as Floodways with the remainder of the floodplain defined as flood fringe (no flood storage):
- All roads, drainage easements or parks inundated by floodwaters,
- All flood liable private property where runoff enters across one boundary and exits partially or fully across another.
Hydraulic Hazard
Low
Medium
High
2yr Mainstream Flood Extent
N
Results in grey area are beyond extent of the study area
J:\Jobs\29034\Arcview\Arcmaps\Figure15a_2yr_Hazard.mxd



J:\Jobs\29034\Arcview\Arcmaps\Figure15b_5yr_Hazard.mxd

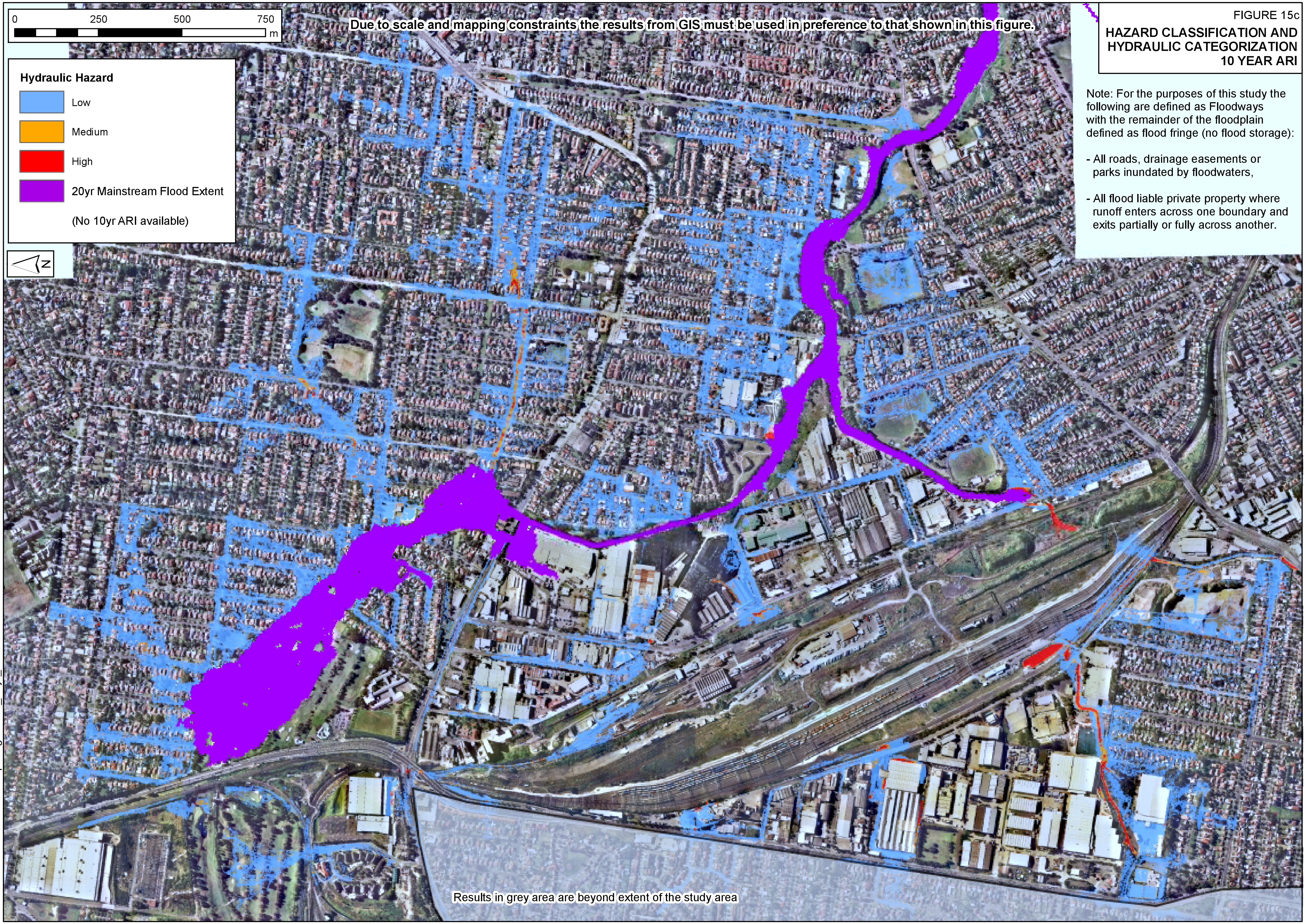


FIGURE 15c
HAZARD CLASSIFICATION AND HYDRAULIC CATEGORIZATION 10 YEAR ARI

J:\Jobs\29034\Arcview\Arcmaps\Figure15c_10yr_Hazard.mxd

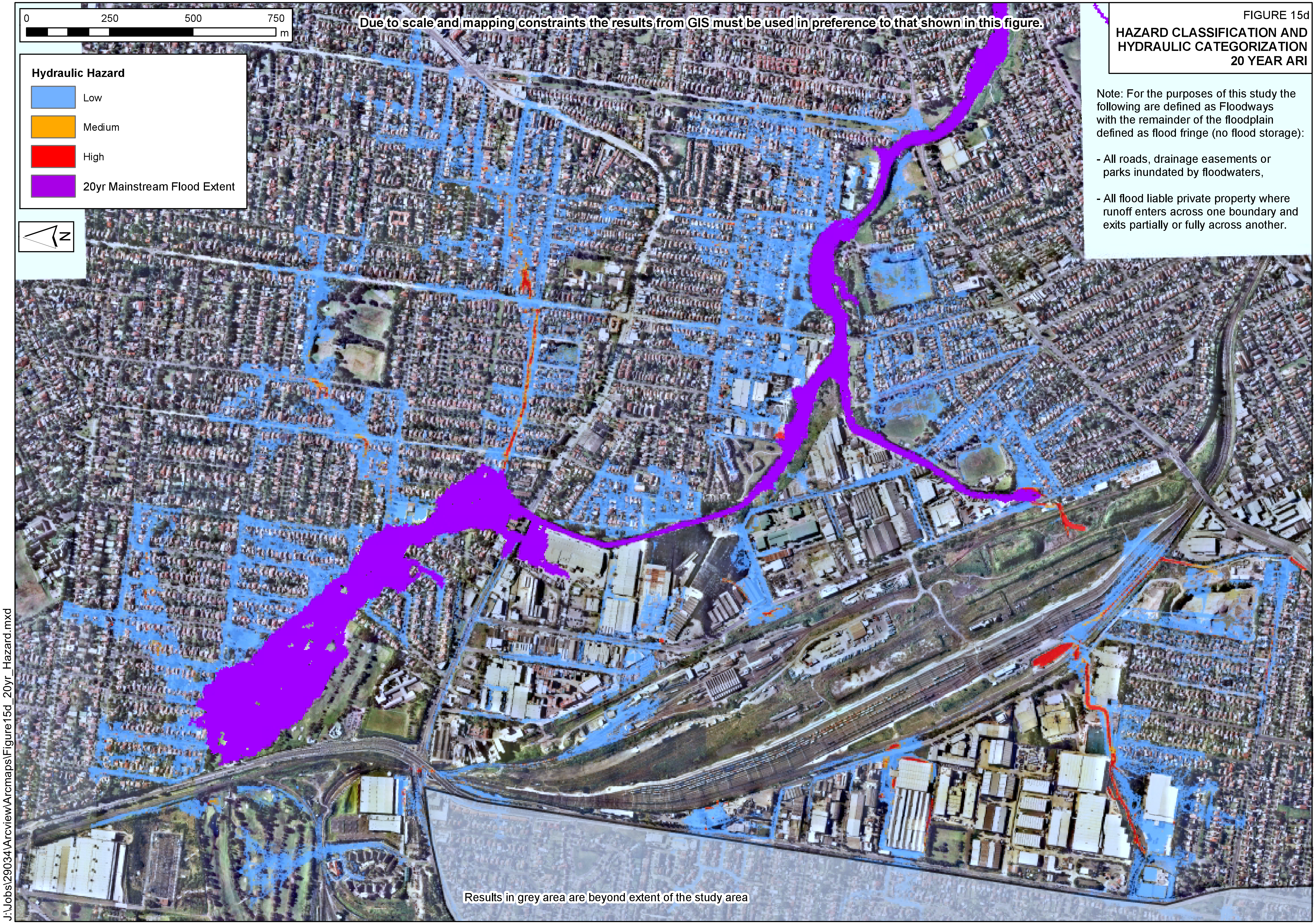


FIGURE 15d
HAZARD CLASSIFICATION AND HYDRAULIC CATEGORIZATION
20 YEAR ARI
0 250 500 750 m
Due to scale and mapping constraints the results from GIS must be used in preference to that shown in this figure.
Hydraulic Hazard
Low
Medium
High
20yr Mainstream Flood Extent
N
Note: For the purposes of this study the following are defined as Floodways with the remainder of the floodplain defined as flood fringe (no flood storage):
- All roads, drainage easements or parks inundated by floodwaters,
- All flood liable private property where runoff enters across one boundary and exits partially or fully across another.
Results in grey area are beyond extent of the study area
J:\Jobs\29034\Arcview\Arcmaps\Figure15d_20yr_Hazard.mxd

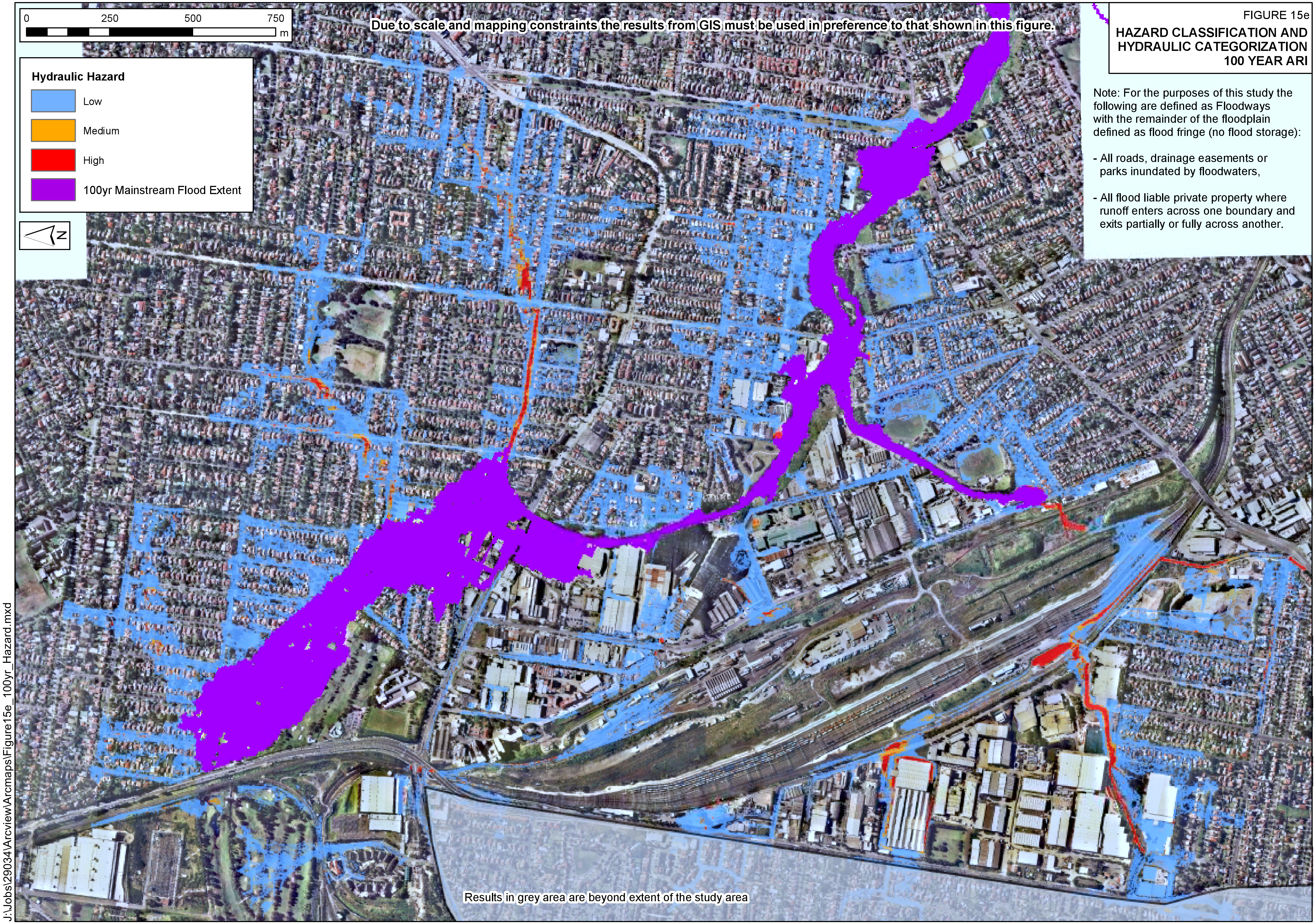
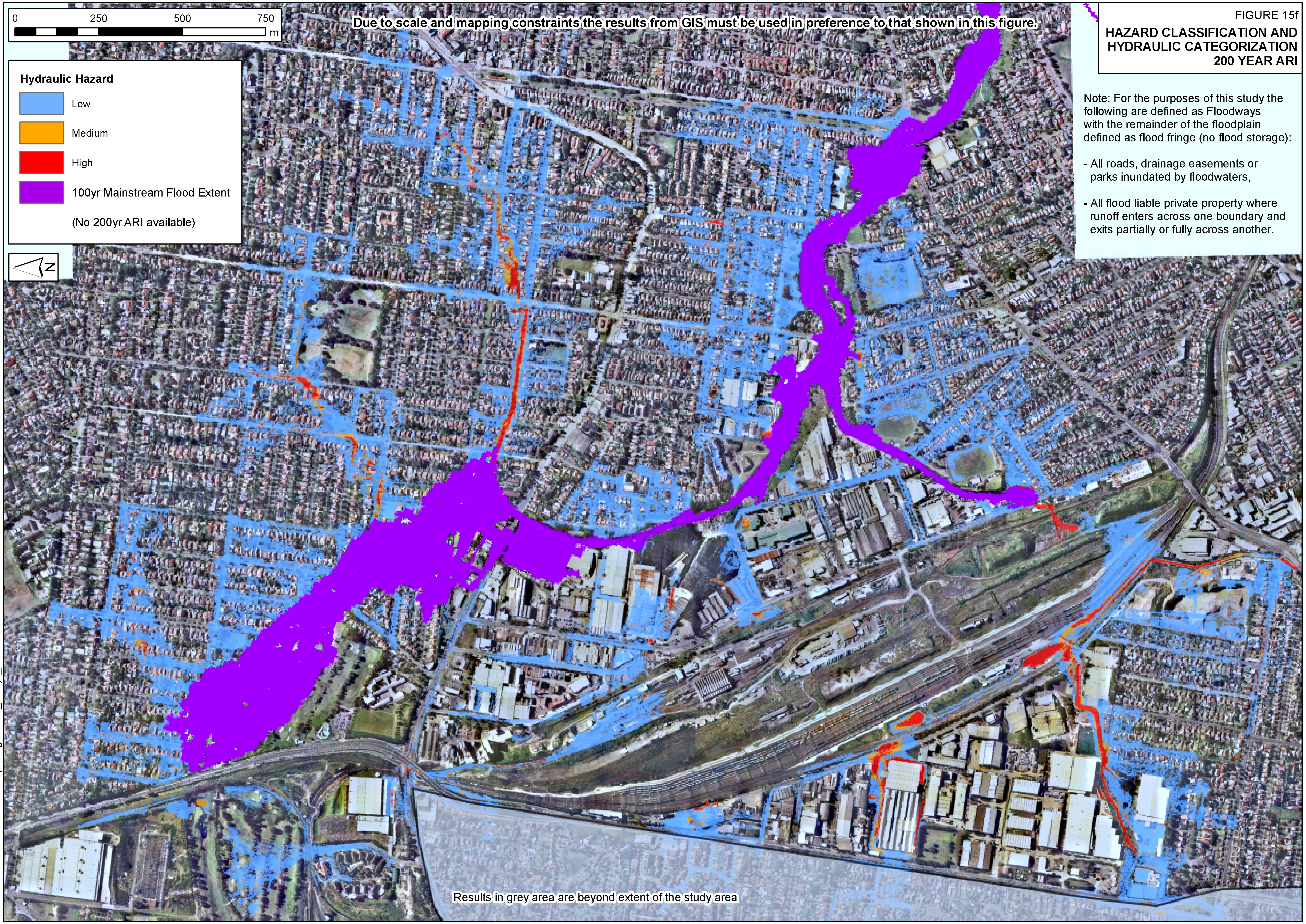

0
250
500
750
m
Due to scale and mapping constraints the results from GIS must be used in preference to that shown in this figure.
Hydraulic Hazard
Low
Medium
High
100yr Mainstream Flood Extent
N
FIGURE 15e
HAZARD CLASSIFICATION AND
HYDRAULIC CATEGORIZATION
100 YEAR ARI
Note: For the purposes of this study the following are defined as Floodways with the remainder of the floodplain defined as flood fringe (no flood storage):
- All roads, drainage easements or parks inundated by floodwaters,
- All flood liable private property where runoff enters across one boundary and exits partially or fully across another.
Results in grey area are beyond extent of the study area
J:\Jobs\29034\Arcview\Arcmaps\Figure15e_100yr_Hazard.mxd

FIGURE 15f

HAZARD CLASSIFICATION AND HYDRAULIC CATEGORIZATION 200 YEAR ARI



Note: For the purposes of this study the following are defined as Floodways with the remainder of the floodplain defined as flood fringe (no flood storage):

- All roads, drainage easements or parks inundated by floodwaters,

- All flood liable private property where runoff enters across one boundary and exits partially or fully across another.

J:\Jobs\29034\Arcview\Arcmaps\Figure15f_200yr_Hazard.mxd

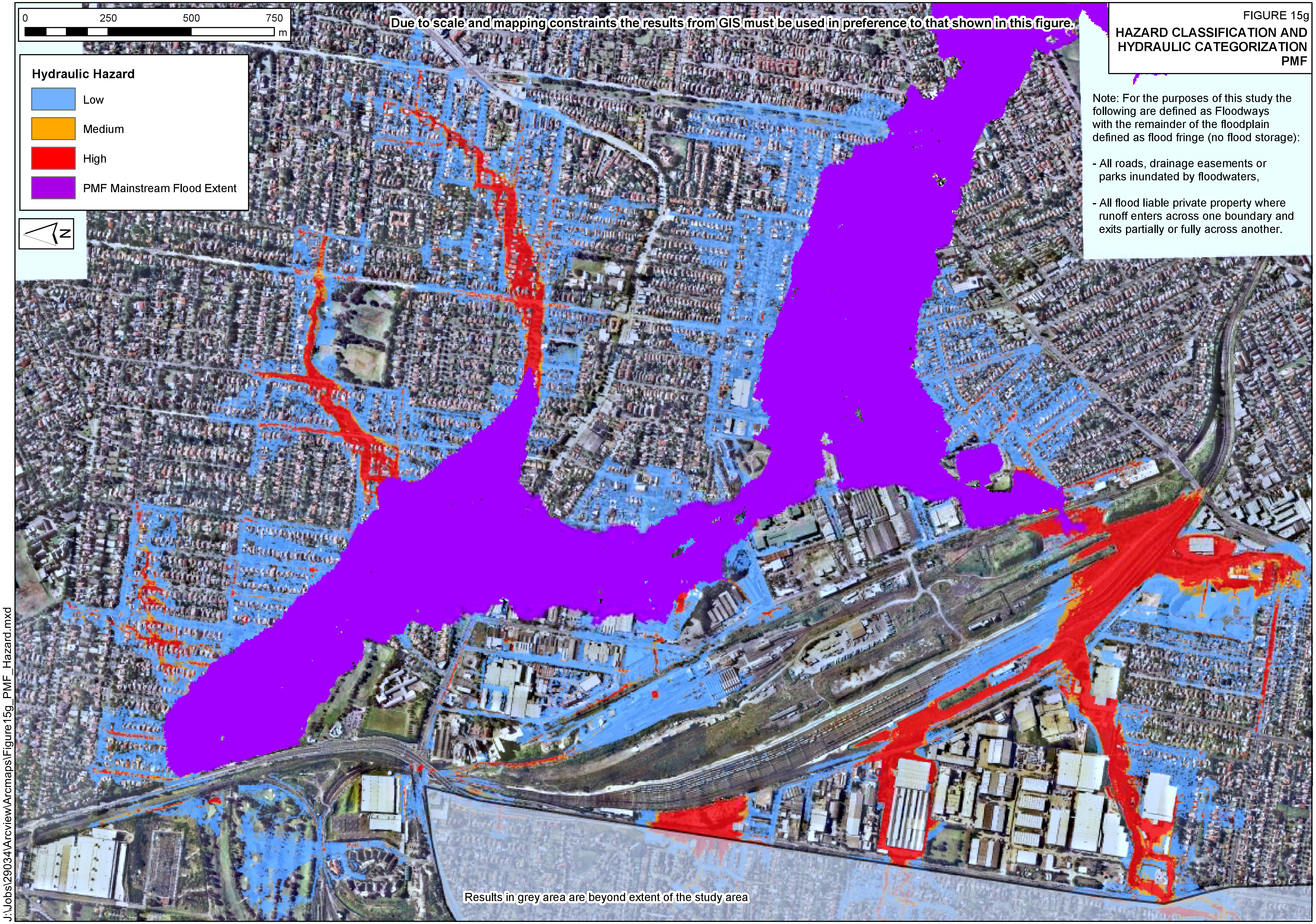


FIGURE 15g
HAZARD CLASSIFICATION AND HYDRAULIC CATEGORIZATION PMF

Appendix A

APPENDIX A: GLOSSARY OF TERMS

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a

	relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
	Area of land which is subject to inundation by floods up to and including the

floodplain	probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the "flood liable land" concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL's are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "standard flood event" in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are

	areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: • the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or • major overland flow paths through developed areas outside of defined drainage reserves; and/or • the potential to affect a number of buildings along the major flow path.
mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage,

	hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to "water level". Both are measured with reference to a specified datum.

stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

APPENDIX B: DRAINAGE FEATURES

The following provides a brief photographic and written description of drainage features in the study area that have been identified as being of relevance for this the study (refer Figure 6 for locations).

Location 1

Barker Road is at the top of catchment. The car park at the Australian Catholic University acts as a retention basin and was used as an inflow point to the hydraulic model.

Pit north of Barker Road

Location 2 and Location 3

No 3 Bareena Street is at a low point and has experienced flooding the garage. 11 Wilson Street has an overland flow path underneath the house, however the floor level has been raised so that if blockage of this flowpath occurs water goes through the garage first rather than the house. Many of the surrounding houses have brick fences that restrict the overland flow path.

3 Bareena Street

Overland flow path under 11 Wilson Street

Location 4

The South Street and Strathlora Street intersection has convertors (pipe connecting across an intersection and exiting to the street on the downstream side). There are no more pits downstream of the convertor along South Street until the intersection with Glenarvon Street. Convertors were not included in DRAINS.

Location 5

Runoff entering 28 Glenarvon Street will be directed to the garage, if this flowpath is blocked runoff will build up in the yard or enter the house.

View to 28 Glenarvon Street

23 Glenarvon Street

Location 6

Stormwater runoff from Council's drainage pipe in Yarrowee Road has been diverted to the newly constructed wetland in Freshwater Park.

Yarrowee Wetland

Cooks River through Freshwater Park upstream of Hedges Avenue

Cooks River downstream of Hedges Avenue

Swale and bio-retention basin in the Chain of Ponds

Location 7

Flooding has occurred near the shops in Cave Road, complaints were received by Council from the owners of the shops about above floor flooding on numerous occasions. As part of Council's Water Sensitive Urban Design program, stormwater runoff from the northern gutter of Cave Road has been diverted to the newly constructed swale and bio-retention basin in the Chain of Ponds.

Location 8

The Weston Milling complex industrial site is adjacent to the old Braidwood Street. A 900 mm diameter pipe enters from the Enfield Marshalling yards and upstream there is a 1000 mm wide by 1000 mm deep open channel. Downstream of the 900 mm pipe runoff enters an open channel which is then piped through a 600mm pipe to Gould Street. Overland flow at this location passes through a weir to 39 Gould Street and then to the inlet structure at 34-48 Cosgrove Road.

900 mm drainage pipe from Roberts Road at Liverpool Road

900 mm pipe and open channel (looking u/s)

Open channel (looking d/s) connecting to the 600 mm pipe to Gould Street and overflow weir

Braidwood Street is no longer a public street and only provides access to the industrial Weston Milling complex site. There is a through connection to Gould Street.

Location 9

There is a blocked pit at the end of Gould Street. Goods have been temporarily stored at the end of Gould Street and it is assumed that this will be cleared and there will be a clear flowpath connecting Gould Street and Cosgrove Road. The TUFLOW modelling has interpolated from the end of Gould Street to Cosgrove Road and has ignored the temporary construction activities.

Blocked inlet pit at the end of Gould Street

Location 10

A Flood Study (Reference 12) was undertaken for the re-development of 34- 48 Cosgrove Road. The inlet structure at the western boundary of 34-48 Cosgrove Road and upstream of the triple cell 1800 mm by 1500 mm box culvert has been constructed to collect overland stormwater runoff from upstream properties.

Large stormwater inlet adjacent to the western boundary of 34-48 Cosgrove Road

Headwall of 1500 mm by 2400 mm southern box culvert through 34-48 Cosgrove Road, behind Prima Coffee site

The semi-natural open channel upstream of the single cell box culvert in Cosgrove Road, adjacent to Cleveland Street is heavily vegetated. There are several recently constructed buildings along Cosgrove Road which are not shown on the current aerial photographs and ALS data.

Location 11

Roberts Road is the divide between Strathfield Municipal and Bankstown City Council LGAs. There are several culverts underneath Roberts Road. The Enfield Marshalling yards provides a major barrier to overland flow and on the upstream side there is considerable temporary floodplain storage.

Culvert and pipes under Roberts Road looking u/s from Boral concrete plant

Pipes under Boral concrete plant (looking u/s)

Location 12

Wentworth Street is a heavily industrial area with No. 25 Wentworth Street experiencing flooding problems in an underground carparkin the past. A box culvert at the intersection of Mayvic Street and Wentworth Street enters the Enfield Marshalling yards (3rd culvert).

Location 13

There is a large de-facto retarding basin within the Enfield Marshalling yards at the southern end of Wentworth Street, opposite a green and golden bell frog conservation area. The 4th culvert under the railway line enters under Wentworth Street near this basin and then joins Coxs Creek.

Culvert under Wentworth Street

Large de-facto retarding basin

Location 14

An open channel exits from twin pipes under Moondo Road, off Roberts Road and continues to the green and golden bell frog conservation area (which is next to the aforementioned basin – near 4th culvert). Upstream of the open channel is the Bankstown Bowling club.

Twin 1650 mm diameter pipe exiting from under the Bankstown Bowling club (looking u/s)

Open channel downstream of Moondo Road (looking d/s)

Location 15

Flow across Juno Parade enters the residential area with a known flood problem at Drew Street.

Location 16

The old quarry near 1-7 Juno Parade has been investigated as part of References 7 and 9. The land on the northern bank has been raised.

1-7 Juno Parade looking d/s

Coxs Creek adjacent to Juno Parade looking d/s

Location 17

Culverts under railway looking u/s from Cosgrove Road

Same location (looking d/s)

Location 18

At this location Coxs Creek and the Cooks River join.

Looking upstream from Water Street

Looking downstream from Coxs Creek and Cooks River junction

Three box culverts from Cosgrove Road carry the runoff which then discharges into the Cooks River. There are no buildings above the culverts. A single culvert (1500 mm by 2400 mm) enters into Cooks River slightly downstream of the aforementioned three culverts.

Outlet of triple 1800 mm by 1500 mm cell box culverts into the Cooks River d/s of Gregory Street

Outlet of 1500 mm by 2400 mm box culverts into the Cooks River d/s of the triple cell outlet

Location 19

Flooding of the Cooks River has resulted in overbank inundation to a depth of approximately 1m at the end of Gregory Street in 1996 (according to residents).

Overland flow path at end of Gregory Street

Timber fence and houses blocking the overland flowpath causing ponding of flood waters

Location 20

Reference 3 indicated a 100 year ARI peak flow of 32 m^3/s at the intersection of High Street and Wallis Avenue. The reserve west of the intersection acts as a flow constriction.

Intersection of High Street and Wallis Avenue

Reserve west of intersection of High Street and Wallis Avenue

Location 21

Past flooding problems at 50, 52 and 54 Long Street have been reported to Council. Runoff enters on the northern side, builds up until it crosses the road and then flows into the garages (according to residents). There is a Sydney Water supply pipe under Long Street which makes it difficult to implement re-grading works to relieve the flooding problem. If the kerb drainage is blocked (by a parked vehicle) there is also likely to be a localised flooding problem.

54 Long Street

21/23 Mintaro Avenue

At 23 Mintaro Avenue the overland flow path is blocked by structures with 21 Mintaro Avenue also experiencing flooding issues. The ground levels also appear to have been raised which alters the overland flow path. As the streets are perpendicular to the flow path runoff tends to flow through the properties rather than along the streets.

Location 22

A development at 11 Cameron Street (Reference 11) proposes a new dwelling with a basement carpark.

Basement car-park under construction at 11 Cameron Street

Existing 5m wide overland flow path at 10 Mount Street

Location 23

At 10 Mount Street: there is an existing (approximately) 5m wide flow path which will be reduced to a 3m width with re-development.

12 CAMERON STREET – RESPONSE TO COMMUNITY INFORMATION SHEET NO 1:

The resident of 12 Cameron Street provided the following photographs of an event in December 2007. Analysis of daily rainfall data for this period was undertaken but this could not indicate the intensity over say a 1 hour period and as there is no nearby pluviometer the event cannot be used for calibration.

Notes from owner 12 Cameron Street

"These photos were taken on two consecutive days the 6th and 7th Dec 2007. Please note the fence palings are now replaced with colour bond fence originally installed with a 200 mm gap at the bottom corner to allow natural water course , this has now been filled in with a fixed sheet of colour bond which I have reported to the Council engineer Said Saqeb."

Front of 12 Cameron Street with ponding in front of driveway

Front of 12 Cameron Street with ponding in front of driveway

Water flowing down the side of 12 Cameron Street past garage

Side area that water flowed down after event finished

Water flowing into driveway during storm

Water ponding at front of 12 Cameron Street during storm

Water ponding at front of 12 Cameron Street during storm

Water ponding at front of 12 Cameron Street during storm

Appendix C

How Do I Get Involved?

Community input to the Flood Study and the subsequent Floodplain Risk Management Study is essential. To make a comment, provide flood information or to seek clarification on any issue, please contact us.

The Project Manager is: **Richard Dewar,**
The Project Engineer is: **Steve Gray.**

Steve can be contacted at

WMAwater
Level 2, 160 Clarence Street
SYDNEY NSW 2000
Telephone: (02) 9299 2855
Facsimile: (02) 9262 6208
Email: gray@wmawater.com.au

The study will be administered by Council. Council's authorised representative is:

Said Saqeb,
Drainage and Development Engineer,
Strathfield Municipal Council
Telephone: (02) 9748 9938
Facsimile: (02) 9748 9914
Email: said.saqeb@strathfield.nsw.gov.au

Community involvement is important at all stages of the Floodplain Management Process. Residents' local knowledge of the catchment and personal experiences of flooding provide an invaluable source of data to define the nature and extent of flooding at the Flood Study stage.

PHOTOGRAPH 7: Looking downstream from Cosgrove Road

During the latter stages where management and planning strategies are outlined, it is important to get community input and feedback to ensure proposed measures meet the needs of the local community.

The importance of community involvement is recognised through the implementation of a community consultation program that is an integral part of each stage of the Floodplain Management Process.

At the Flood Study stage information on actual flooding or drainage problems that have taken place is very helpful in ascertaining the performance of the existing drainage system and identifying problem areas.

At the Floodplain Risk Management Stage members of the community will be asked by local newspaper advertisement to provide information and feedback in planning the best way to improve the management of the catchment with regard to minimising flood risk.

PHOTOGRAPH 8: Cooks River looking downstream from Water Street

STRATHFIELD COUNCIL

Cooks River & Coxs Creek Flood Study

Community Information Sheet No. 1 July 2009

Introduction

Under the NSW Government's Flood Prone Land Policy, management of flood prone land is primarily the responsibility of councils.

Strathfield Municipal Council has appointed WMAwater - *Water and Environmental Engineers* to carry out a Flood Study of the Cooks River and Coxs Creek catchments within the Strathfield local government area (LGA).

This Flood Study will define the nature and extent of flooding. It will provide a basis for sound floodplain management planning for the Strathfield Municipal Council part of the catchment, whilst recognising the demands for development and change, the need for good urban and environmental outcomes, and the social and economic benefits of reducing flood damages.

The Flood Study is funded under the NSW Government's Floodplain Management Program. On completion of the study any mitigation measures recommended may be eligible for State and/or Federal government funding.

Please provide any information that would be of use in the preparation of the Flood Study. This information might include:

- photographs of flooding,
- memory/description of flooding,
- records of flood heights.

Known dates of flooding are:

- August 1986,
- May 1988,
- February 1990.

The Study Area

The Cooks River and Coxs Creek have a combined catchment area of approximately 22km^2 contributing up to Punchbowl road. The contributing catchment includes some areas from the suburbs of Strathfield South, Enfield, Enfield South, Rookwood, Belfield, Chullora, Potts Hill, Bankstown North, Greenacre, Punchbowl, Mt Lewis, Wiley Park, Roselands, and Belmore.

Stormwater within this section is carried within the underground piped network and open channel system, or when this is exceeded, along roads or through private property.

The study area (refer Figure 1) is the area of the catchment within the Strathfield Council LGA.

FIGURE 1: Study Area

Floodplain Management Process

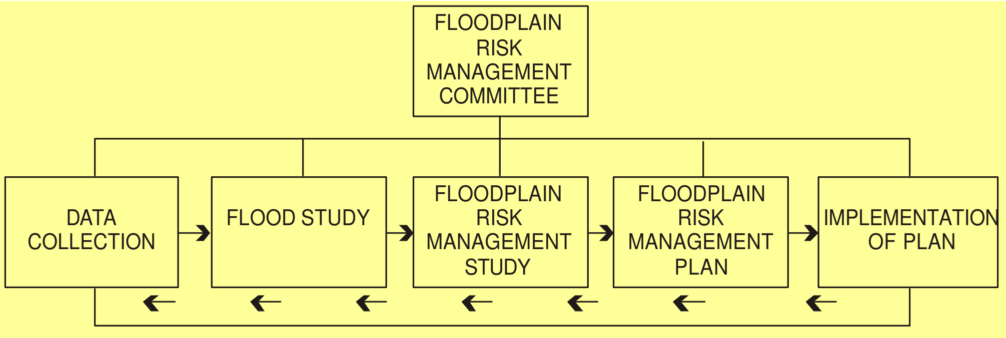


DIAGRAM 1: The Floodplain Risk Management Process

The first step in the overall floodplain management process (Diagram 1) is data collection and preparation of the Flood Study.

The Flood Study

Currently WMAwater has been appointed to carry out the Flood Study for the area defined in Figure 1.

The Flood Study involves a comprehensive technical investigation of the nature and extent of flooding within the study area.

PHOTOGRAPH 1: Cooks River through Chain of Ponds near Cave Road

PHOTOGRAPH 2: Culverts underneath Roberts Road

PHOTOGRAPH 3: De-facto retarding basin downstream of Wentworth Road

PHOTOGRAPH 4: Junction of Cooks River and Coxs Creek at Water Street

The Floodplain Risk Management Study

The second step in the overall floodplain risk management process is the preparation of the Floodplain Risk Management Study (FRMS) that identifies a range of floodplain management measures to address the problems and areas of concern identified in the flood study.

PHOTOGRAPH 5: Long Street – previous drainage issues

PHOTOGRAPH 6: Flooding hotspot at the intersection of High Street and Wallis Avenue. Flow moves from photo bottom right to top left

The Floodplain Risk Management Plan

The third stage in the overall risk management process involves preparation of a Plan that documents how the proposed measures identified in the FRMS are to be implemented in terms of resources and timing.

The final stage of the process is the undertaking of the works.

Community Consultation Program Public Exhibition of Draft

A draft of the Flood Study will be placed on public exhibition for comments and questions prior to finalisation. We will advise the date in due course.

Once the Flood Study has been completed, and the flood behaviour of the catchment is defined, Council will then commence the next stage of the project, the Floodplain Risk Management Study.

We will inform you of this and provide contacts for you to give input or voice any questions or concerns you may have.

Appendix D

wma water

STRATHFIELD COUNCIL

Cooks River and Coxs Creek Flood Study

PROPERTY OWNER QUESTIONNAIRE – September 2009

Dear Resident,

As you will be aware from a recently distributed community information sheet and coverage in Council's community news column, Council has engaged WMAwater to undertake the Cooks River and Coxs Creek Flood Study.

The purpose of this study is to accurately define the nature and extent of flooding, and provide a basis for sound floodplain management planning for the catchment. The study will recognise the demands for development, the social and economic benefits of reducing flood damage, and the need for good urban and environmental outcomes.

In order to ensure this study adequately addresses these issues, we have prepared this questionnaire. Please take time to answer the following questions as accurately as possible. If you have any photographs of flooding in your area, it would be greatly appreciated if you could send along with completed questionnaire by 30th October, 2009. Please use the **prepaid self-addressed envelope provided**, fax to 9262 6208, or scan and email to dewar@wmawater.com.au.

Contact Details

Please note that the return of the completed questionnaire is voluntary and any personal information included in the questionnaire will be subject to the Privacy & Personal Information Protection Act 1998. This information will only be used as an input into the Cooks River and Coxs Creek Flood Study.

Contact Name: ______________________ Tel No: ______________________

Address: ______________________ E-Mail ______________________

☐ Residential Property ☐ Non-Residential Property

Flood Related Information

How long have you lived at this address (tick for length of residency)?

☐ Less than 5 Years ☐ 5 – 10 Years ☐ 10 – 15 Years ☐ 15 – 30 Years ☐ More than 30 Years

Are you aware of any of the following flood events (tick for yes)?

☐ August 1986 ☐ May 1988 ☐ February 1990

Has your property ever been inundated by floodwaters, if so when (list all events)?

____

And were any building floors inundated (tick for yes)? ☐ House ☐ Building other than house

Can you identify the peak level reached by floodwaters (tick for yes)? An example of a peak level may be a debris mark, a water line, or say you recall the water reached the top of the 2nd step. Please be as accurate as possible.

☐ No ☐ Yes, on my property ☐ Yes, outside my property

If yes, please provide a brief description over the page or photograph the flood mark & email it to us.

Please include or email any photographs of flooding in and around your property.Can we contact you for more information (please tick)? ☐ Yes ☐ No

Contact Details: Richard Dewar: WMAwater – Water & Environmental Engineers
Level 2/160 Clarence St, Sydney, NSW, 2000 Ph: 9299 2855 Fax: 9262 6208 Email: dewar@wmawater.com.au

Appendix E

Pipe	Existing	number	Upgraded Diameter							
Name	Dia.	of pipes	2y	no.	10y	no.	20y	no.	100y	no.
p7000	300	1								
p7002	300	1								
p7006	300	1			450	1	450	1	525	1
p7010	450	1							525	1
p7014	450	1			525	1	525	1	600	1
p7018	450	1			525	1	525	1	600	1
p7022	450	1	525	1	675	1	750	1	825	1
p7028	750	1			825	1	900	1	1050	1
p7038	750	1	825	1	1050	1	1050	1	1200	1
p7004	300	1			375	1	450	1	450	1
p7008	375	1								
p7016	300	1					375	1	375	1
p7020	375	1	525	1	600	1	675	1	750	1
p7024	300	1								
p7026	300	1	450	1	525	1	525	1	600	1
p7030	375	1					450	1	450	1
p7032	375	1			525	1	525	1	600	1
p7034	375	1			525	1	525	1	600	1
p7036	450	1			525	1	525	1	600	1
p7037	450	1			525	1	525	1	600	1
p7084	375	1	600	1	675	1	750	1	825	1
p7088	375	1	675	1	750	1	825	1	900	1
p7090	450	1	675	1	750	1	825	1	900	1
p7094	450	1	675	1	900	1	1050	1	1050	1
p7095	450	1	675	1	900	1	1050	1	1050	1
p7086	375	1								
p7092	375	1							450	1
p7096	375	1	525	1	600	1	675	1	600	1
p7098	375	1	525	1	675	1	750	1	750	1
p7100	375	1	600	1	750	1	750	1	900	1
p7108	450	1	600	1	750	1	750	1	900	1
p7110	450	1	600	1	750	1	750	1	900	1
p7111	450	1	600	1	750	1	750	1	900	1
p7102	375	1					450	1	450	1
p7104	450	1					525	1	525	1
p7106	375	1								
p7114	375	1							450	1
p7116	375	1							450	1
p7118	375	1							450	1
p7120	375	1	450	1	600	1	600	1	675	1
p7122	375	1	525	1	675	1	675	1	750	1
p7126	525	1	675	1	750	1	1050	1	900	1
p7128	525	1	750	1	900	1	1050	1	900	1
p7132	525	1	825	1	1050	1	1200	1	1050	1
p7136	525	1	825	1	1050	1	1200	1	1050	1
p7138	525	1	825	1	1050	1	1200	1	1050	1
p7124	375	1							450	1
p7130	450	1								
p7134	300	1							375	1
p7142	300	1	525	1	675	1	750	1	825	1
p7144	300	1	525	1	675	1	750	1	825	1
p7145	300	1	525	1	675	1	750	1	825	1
p7156	300	1	375	1	525	1	525	1	600	1
p7158	300	1	375	1	525	1	525	1	600	1
p7160	300	1	375	1	525	1	525	1	600	1
p7164	375	1	450	1	525	1	525	1	600	1
p7166	375	1	450	1	525	1	525	1	600	1
pWMA67	375	1	750	1	1050	1	1050	1	1350	1
p14049	375	1	750	1	1050	1	1050	1	1350	1
pWMA34	600	1	750	1	1050	1	1050	1	1350	1
pWMA42	600	1	750	1	1050	1	1050	1	1350	1
pWMA33	600	1	825	1	1050	1	1050	1	1350	1
pWMA74	600	1	825	1	1050	1	1050	1	1350	1
pWMA75	600	1	825	1	1050	1	1050	1	1350	1
pWMA31	600	1	825	1	1050	1	1050	1	1350	1
pWMA30	600	1	825	1	1050	1	1050	1	1350	1
pWMA68	750	1	825	1	1050	1	1050	1	1350	1
pWMA69	750	1	825	1	1050	1	1050	1	1350	1
pWMA29	750	1	825	1	1050	1	1050	1	1350	1
pWMA28	750	1	1050	1	1200	1	1200	1	1350	1
pWMA26	900	1	1050	1	1200	1	1200	1	1350	1
pWMA25	900	1	1050	1	1200	1	1350	1	1350	1
pWMA24	1200	1					1500	1	1500	1
pWMA22	1200	1					1500	1	1500	1
pWMA41	1200	1			1350	1	1500	1	1500	1
p7165	375	1								
p7167	375	1								
pWMA39	375	1								
pWMA44	375	1			450	1	450	1	450	1
pWMA40	375	1	450	1	600	1	600	1	675	1
pWMA36	525	1	600	1	675	1	750	1	750	1
pWMA43	525	1	600	1	675	1	750	1	825	1
pWMA35	525	1	675	1	825	1	750	1	825	1
p7168	375	1								
p7170	300	1								
p7172	375	1								
p7174	300	1								
p7180	300	1	375	1	450	1	450	1	525	1
p7182	300	1	375	1	450	1	450	1	525	1
p7176	300	1	375	1	450	1	450	1	525	1
p7178	300	1	375	1	450	1	450	1	525	1
p7184	375	1								
p8000	450	1	675	1	825	1	900	1	1050	1
p8002	450	1	750	1	1050	1	1200	1	1200	1
p8006	450	1	825	1	1200	1	1350	1	1350	1
p8010	300	1	1050	1	1200	1	1350	1	1350	1
p8017	600	1	1050	1	1200	1	1350	1	1350	1
p8021	900	1	1050	1	1200	1	1350	1	1500	1
p8026	900	1	1050	1	1350	1	1500	1	1500	1
p8031	900	1	1200	1	1350	1	1500	1	1650	1
p8035	1200	1			1350	1	1500	1	1650	1
p8004	375	1	450	1	600	1	600	1	675	1
p8008	300	1								
p8011	300	1	450	1	600	1	600	1	675	1
p8013	300	1	600	1	825	1	750	1	1050	1
p8012	300	1	525	1	675	1	750	1	750	1
p8014	300	1	600	1	675	1	600	1	675	1
p8016	300	1	600	1	675	1	750	1	825	1
p8018	525	1	750	1	900	1	1050	1	1050	1
p8020	525	1	750	1	1050	1	1050	1	1200	1
p8019	375	1								

Pipe	Existing	number	Upgraded Diameter							
Name	Dia.	of pipes	2y	no.	10y	no.	20y	no.	100y	no.
p11050	450	1	600	1	750	1	825	1	825	1
p11052	450	1	600	1	750	1	825	1	825	1
p11054	450	1	600	1	750	1	825	1	825	1
p11056	600	1			750	1	825	1	825	1
p11060	600	1			750	1	825	1	825	1
p11062	600	1			750	1	825	1	825	1
p11064	600	1	675	1	825	1	1050	1	900	1
p11068	600	1	750	1	900	1	1050	1	1050	1
p11070	600	1	900	1	1050	1	1050	1	1200	1
p11058	375	1								
p11066	375	1							450	1
p11074	300	1	450	1	525	1	600	1	675	1
p11076	450	1	525	1	600	1	675	1	750	1
p11078	450	1	600	1	750	1	675	1	750	1
p11080	450	1	600	1	750	1	750	1	825	1
p11084	450	1	600	1	750	1	750	1	825	1
p11086	450	1	600	1	750	1	750	1	825	1
p11082	450	1								
p11090	375	1	450	1	525	1	600	1	600	1
p11094	375	1	675	1	825	1	825	1	900	1
p11098	600	1	675	1	900	1	1050	1	1050	1
p11104	600	1	900	1	1050	1	1050	1	1050	1
p11108	600	1	900	1	1200	1	1050	1	1350	1
p11112	600	1	900	1	1200	1	1200	1	1350	1
p11116	600	1	900	1	1200	1	1200	1	1350	1
p11118	600	1	1050	1	1350	1	1500	1	1350	1
p11122	600	1	1050	1	1350	1	1500	1	1500	1
p11128	600	1	1050	1	1350	1	1500	1	1650	1
p11130	600	1	1050	1	1350	1	1650	1	1650	1
p11132	900	1	1050	1	1350	1	1650	1	1650	1
p11134	900	1	1050	1	1350	1	1650	1	1650	1
p11092	375	1	600	1	600	1	675	1	750	1
p11096	375	1	525	1	525	1	600	1	675	1
p11100	375	1	525	1	600	1	675	1	600	1
p11102	375	1	525	1	675	1	750	1	750	1
p11106	375	1	525	1	675	1	600	1	675	1
p11110	375	1	450	1	525	1	525	1	600	1
p11114	375	1								
p11120	375	1					450	1	450	1
p11124	375	1								
p11126	375	1								
p11136	300	1			375	1	450	1	450	1
p11138	300	1	600	1	600	1	600	1	675	1
p11140	450	1	600	1	675	1	675	1	750	1
p11142	450	1	600	1	675	1	675	1	750	1
p11144	450	1	600	1	675	1	675	1	750	1
p11146	450	1	600	1	675	1	675	1	750	1
p11150	375	1					450	1	450	1
p11152	375	1			450	1	525	1	525	1
p11154	375	1			525	1	525	1	525	1
p11158	375	1			525	1	525	1	525	1
p11160	450	1			525	1	525	1	525	1
p11162	450	1			525	1	525	1	600	1
p11164	450	1	525	1	600	1	675	1	600	1
p11166	450	1	525	1	600	1	675	1	600	1
p11156	375	1								
p11170	375	1								
p11172	450	1								
p11174	450	1					525	1	525	1
p11179	450	1	525	1	675	1	675	1	825	1
p11224	900	1	1200	1	1500	1	1650	1	1800	1
p11234	900	1	1200	1	1500	1	1800	1	1800	1
p11236	900	1	1200	1	1500	1	1800	1	1800	1
p11242	900	1	1200	1	1500	1	1800	1	1800	1
p11244	900	1	1200	1	1500	1	1800	1	1800	1
p11250	900	1	1350	1	1650	1	1800	1	1950	1
p11252	1050	1	1350	1	1650	1	1800	1	1950	1
p11254	1050	1	1350	1	1650	1	1800	1	1950	1
p11176	375	1							450	1
p11178	300	1	450	1	525	1	600	1	525	1
p11180	300	1								
p11182	525	1								
p11184	525	1								
p11188	600	1							675	1
p11196	600	1	675	1	825	1	825	1	1050	1
p11200	600	1	900	1	1050	1	900	1	1050	1
p11204	750	1	900	1	1050	1	1200	1	1350	1
p11208	750	1	1200	1	1350	1	1500	1	1650	1
p11212	750	1	1200	1	1500	1	1500	1	1650	1
p11214	750	1	1200	1	1500	1	1650	1	1800	1
p11186	300	1	450	1	600	1	600	1	675	1
p11190	375	1	450	1	525	1	525	1	600	1
p11192	375	1	450	1	525	1	600	1	675	1
p11194	300	1	600	1	600	1	750	1	675	1
p11198	300	1	525	1	675	1	750	1	750	1
p11202	300	1	525	1	675	1	675	1	750	1
p11206	300	1	525	1	675	1	600	1	675	1
p11210	300	1	450	1	600	1	600	1	675	1
p11216	300	1								
p11218	300	1			375	1	375	1	375	1
p11220	300	1	375	1	375	1	450	1	450	1
p11222	450	1								
p11226	375	1			450	1	450	1	525	1
p11228	375	1	525	1	675	1	675	1	750	1
p11232	375	1	525	1	750	1	675	1	750	1
p11230	375	1								
p11238	300	1	450	1	525	1	525	1	600	1
p11240	300	1	525	1	675	1	750	1	750	1
p11246	300	1	600	1	675	1	600	1	675	1
p11248	300	1	600	1	750	1	825	1	825	1
p11258	375	1	750	1	900	1	900	1	1050	1
p11260	375	1	750	1	900	1	900	1	1050	1
p11264	375	1								
p11266	375	1							450	1
p11270	375	1	450	1	600	1	600	1	600	1
p11274	375	1	600	1	750	1	675	1	825	1
p11276	375	1	600	1	750	1	825	1	900	1
p11278	375	1	600	1	750	1	825	1	900	1
p11280	450	1	600	1	750	1	825	1	900	1
p11284	450	1	600	1	750	1	825	1	900	1
p11286	0.8W x 0.5H	1	675	1	825	1	825	1	900	1

Pipe Name	Existing Dia.	number of pipes	Upgraded Diameter 2y	no.	10y	no.	20y	no.	100y	no.
p8024	375	1			450	1	450	1	525	1
p8025	900	1								
p8029	375	1	600	1	750	1	675	1	750	1
p8030	375	1	675	1	825	1	900	1	900	1
p8048	450	1	675	1	825	1	1050	1	1200	1
p8050	600	1	825	1	1050	1	1050	1	1200	1
p8052	600	1	825	1	1050	1	1050	1	1200	1
p8060	0.45W x 0.4H	1	525	1	675	1	825	1	825	1
p8062	0.45W x 0.4H	1	1050	1	1200	1	1200	1	1500	1
p8066	750	1			900	1	1050	1	1050	1
p8072	750	1	825	1	1050	1	1050	1	1200	1
p8064	375	1								
p8068	0.45W x 0.4H	1	300	1	375	1	450	1	450	1
p8070	375	1	575	1	525	1	525	1	525	1
p8084	375	1			525	1	600	1	525	1
p8086	900	1								
p8090	900	1								
p8096	1200	1								
p8088	375	1								
p8092	375	1	825	1	1200	1	1050	1	1200	1
p8094	375	1	825	1	1200	1	1050	1	1200	1
p8104	375	1	525	1	675	1	750	1	825	1
p8106	375	1	525	1	675	1	750	1	825	1
p8112	450	1	750	1	900	1	1050	1	1050	1
p8116	675	1	900	1	1050	1	1200	1	1200	1
p8158	1200	1	1500	1	1650	1	1800	1	1950	1
p8176	900	1	1800	1	2550	1	2550	1	2550	1
p8180	1200	1	1800	1	2550	1	2550	1	2550	1
p8183	1200	1	1800	1	2550	1	2550	1	2550	1
p8184	1350	1	1800	1	2550	1	2550	1	2550	1
p8220	1350	1	1800	1	2550	1	2550	1	2550	1
p8225	1350	1	1800	1	2550	1	2550	1	2550	1
p8227	1350	1	1800	1	2550	1	2550	1	2550	1
p8229	1350	1	1800	1	2550	1	2550	1	2550	1
p8108	375	1	450	1	525	1	600	1	600	1
p8110	375	1	525	1	600	1	675	1	600	1
p8111	375	1	525	1	600	1	675	1	600	1
p8114	375	1	600	1	750	1	825	1	1050	1
p8117	300	1	450	1	600	1	600	1	525	1
p8118	375	1	450	1	600	1	600	1	600	1
p8120	375	1	450	1	600	1	600	1	675	1
p8122	375	1	450	1	600	1	600	1	675	1
p8126	375	1	825	1	1050	1	1050	1	1050	1
p8128	375	1	825	1	1050	1	1050	1	1050	1
p8136	450	1	825	1	1050	1	1050	1	1050	1
p8268	300	1			375	1	375	1	375	1
p8270	300	1			375	1	375	1	375	1
p8138	450	1	825	1	1050	1	1050	1	1200	1
p8140	525	1	825	1	1050	1	1050	1	1200	1
p8146	600	1	825	1	1050	1	1050	1	1200	1
p8148	600	1	900	1	1050	1	1050	1	1200	1
p8124	375	1	600	1	675	1	750	1	825	1
p8130	375	1								
p8132	375	1	675	1	750	1	825	1	825	1
p8134	375	1	675	1	750	1	825	1	900	1
p8142	375	1								
p8144	375	1	600	1	750	1	825	1	1050	1
p8147	300	1								
p8150	375	1	675	1	825	1	900	1	1050	1
p8152	450	1	825	1	900	1	1050	1	1200	1
p8154	375	1	900	1	1050	1	1200	1	1350	1
p8156	600	1	1050	1	1050	1	1200	1	1350	1
p8160	450	1	600	1	750	1	825	1	900	1
p8162	450	1	675	1	825	1	900	1	1050	1
p8164	450	1	675	1	825	1	900	1	1050	1
p8168	450	1	750	1	1050	1	1050	1	1200	1
p8172	450	1	900	1	1050	1	1200	1	1350	1
p8174	750	1	900	1	1050	1	1200	1	1350	1
p8166	375	1	600	1	600	1	675	1	750	1
p8170	375	1								
p8178	375	1								
p8182	375	1	525	1	600	1	525	1	600	1
p8186	300	1	375	1	450	1	450	1	525	1
p8188	375	1			450	1	450	1	525	1
p8192	375	1	450	1	600	1	600	1	750	1
p8198	450	1	600	1	675	1	675	1	750	1
p8204	525	1	600	1	750	1	825	1	900	1
p8207	525	1	675	1	825	1	900	1	1050	1
p8214	525	1	750	1	900	1	1050	1	1050	1
p8218	1.2W x 0.9H	1	750	1	900	1	1050	1	1050	1
p8190	375	1	450	1	600	1	600	1	525	1
p8194	375	1	600	1	675	1	600	1	675	1
p8196	375	1	600	1	675	1	675	1	750	1
p8200	375	1	525	1	600	1	525	1	600	1
p8202	375	1	525	1	600	1	675	1	675	1
p8205	375	1	450	1	600	1	525	1	675	1
p8206	450	1			600	1	525	1	675	1
p8208	0.4W x 0.225H	1	300	1	375	1	450	1	450	1
p8210	375	1	525	1	675	1	600	1	675	1
p8212	375	1	525	1	675	1	600	1	750	1
p8216	375	1								
p8222	375	1	450	1	525	1	525	1	600	1
p8224	375	1	450	1	525	1	600	1	675	1
p8226	375	1			450	1	525	1	525	1
p8228	375	1								
p8234	300	1	525	1	600	1	675	1	600	1
p8237	450	1	600	1	750	1	825	1	750	1
p8241	450	1	600	1	750	1	825	1	900	1
p8244	450	1	600	1	750	1	825	1	900	1
p8236	300	1	600	1	750	1	675	1	750	1
p8238	300	1								
p8240	375	1							450	1
p8242	300	1	525	1	675	1	750	1	825	1
p8256	300	1	450	1	525	1	600	1	600	1
p8259	300	1	675	1	750	1	825	1	1050	1
p8261	450	1	750	1	900	1	1050	1	1050	1
p8262	600	1	750	1	900	1	1200	1	1350	1
p8264	600	1	750	1	1050	1	1200	1	1350	1
p8265	375	1	900	1	1050	1	1200	1	1350	1
p8258	300	1	675	1	750	1	825	1	1050	1
p8260	450	1			525	1	600	1	675	1

Pipe Name	Existing Dia.	number of pipes	Upgraded Diameter 2y	no.	10y	no.	20y	no.	100y	no.
p11290	600	1	750	1	825	1	750	1	825	1
p11296	600	1	750	1	825	1	750	1	825	1
p11304	600	1	750	1	825	1	825	1	900	1
p11310	600	1	750	1	825	1	825	1	900	1
p11316	600	1	750	1	825	1	900	1	1050	1
p11320	600	1	750	1	900	1	900	1	1050	1
p11324	600	1	750	1	900	1	900	1	1050	1
p11330	600	1	750	1	900	1	1050	1	1050	1
p11334	600	1	750	1	900	1	1050	1	1050	1
p11338	375	1	750	1	900	1	1050	1	1050	1
p11268	300	1								
p11272	375	1			450	1	525	1	525	1
p11282	300	1								
p11288	300	1			375	1	450	1	450	1
p11292	375	1								
p11294	375	1	525	1	525	1	675	1	600	1
p11300	300	1	450	1	525	1	600	1	675	1
p11302	300	1	450	1	600	1	600	1	675	1
p11306	375	1								
p11308	375	1							450	1
p11314	300	1	375	1	450	1	450	1	525	1
p11318	300	1	375	1	450	1	525	1	525	1
p11322	375	1								
p11328	0.4W x 0.225H	1	450	1	525	1	525	1	600	1
p11332	375	1								
p11336	375	1								
p11342	225	1	450	1	600	1	600	1	675	1
p11344	375	1	525	1	675	1	675	1	750	1
p11346	375	1	525	1	675	1	750	1	750	1
p11348	375	1	750	1	825	1	825	1	1050	1
p11356	600	1	825	1	825	1	1050	1	1200	1
p11372	900	1			1200	1	1200	1	1350	1
p11374	900	1			1200	1	1200	1	1350	1
p11376	900	1			1200	1	1200	1	1350	1
p11378	900	1			1200	1	1200	1	1350	1
p11380	900	1	1050	1	1350	1	1350	1	1500	1
p11384	900	1	1050	1	1350	1	1350	1	1500	1
p11390	900	1	1050	1	1350	1	1350	1	1500	1
p11392	1050	1			1350	1	1350	1	1500	1
p11394	1050	1			1350	1	1350	1	1500	1
p11396	1050	1			1350	1	1350	1	1500	1
p11397	1050	1			1350	1	1350	1	1500	1
p11398	1050	1			1350	1	1350	1	1500	1
p11350	375	1					450	1	450	1
p11352	375	1					450	1	450	1
p12054	375	1			450	1	450	1	525	1
p12062	375	1	450	1	525	1	525	1	600	1
p11354	450	1								
p11358	300	1	525	1	675	1	750	1	825	1
p11360	375	1	600	1	750	1	750	1	825	1
p11368	375	1	750	1	900	1	900	1	1050	1
p11362	375	1								
p11364	375	1								
p11366	375	1								
p11382	375	1								
p11386	375	1			450	1	450	1	450	1
p11388	375	1			450	1	450	1	450	1
p11393	225	1	300	1	300	1	375	1	375	1
p11395	300	1			375	1	375	1	450	1
p11402	375	1	450	1	600	1	600	1	675	1
p11404	375	1	525	1	675	1	675	1	750	1
p11410	375	1	600	1	675	1	750	1	825	1
p11414	375	1	600	1	750	1	825	1	1050	1
p11418	375	1	750	1	900	1	900	1	1050	1
p11420	375	1	825	1	1050	1	1050	1	1200	1
p11424	375	1	825	1	1050	1	1050	1	1200	1
p11430	750	1	825	1	1050	1	1050	1	1200	1
p11434	750	1	825	1	1050	1	1050	1	1200	1
p11438	750	1	825	1	1050	1	1050	1	1200	1
p11406	375	1	600	1	675	1	600	1	675	1
p11408	375	1	600	1	675	1	675	1	750	1
p11412	375	1			450	1	450	1	525	1
p11416	375	1								
p11422	375	1								
p11426	375	1	675	1	825	1	900	1	1200	1
p11428	375	1	750	1	900	1	1050	1	1200	1
p11432	375	1			450	1	450	1	450	1
p11436	375	1			525	1	525	1	600	1
p12000	300	1	525	1	675	1	675	1	750	1
p12002	375	1	600	1	750	1	675	1	750	1
p12006	375	1	600	1	750	1	825	1	825	1
p12010	375	1	600	1	750	1	825	1	825	1
p12016	375	1	600	1	750	1	825	1	825	1
p12028	525	1	825	1	1050	1	1050	1	1200	1
p12032	525	1	825	1	1050	1	1050	1	1200	1
p12038	600	1	900	1	1050	1	1200	1	1200	1
p12004	0.4W x 0.225H	1	450	1	600	1	525	1	675	1
p12008	0.4W x 0.225H	1	300	1	375	1	375	1	375	1
p12012	0.4W x 0.225H	1	375	1	450	1	525	1	525	1
p12014	375	1			450	1	525	1	525	1
p12018	375	1								
p12020	375	1	450	1	525	1	525	1	600	1
p12022	375	1	450	1	525	1	525	1	600	1
p12024	375	1	450	1	525	1	525	1	600	1
p12026	375	1	450	1	525	1	525	1	600	1
p12030	375	1			450	1	525	1	525	1
p12034	525	1								
p12036	375	1								
p12046	375	1							450	1
p12052	375	1	450	1	525	1	525	1	600	1
p12056	450	1	525	1	600	1	675	1	600	1
p12058	450	1	600	1	600	1	750	1	900	1
p12060	450	1	600	1	675	1	750	1	900	1
p12064	450	1	600	1	675	1	750	1	900	1
p12068	525	1	675	1	750	1	825	1	900	1
p12074	525	1	750	1	750	1	900	1	1050	1
p12076	525	1	825	1	900	1	900	1	1200	1
p12078	525	1	825	1	900	1	1050	1	1200	1
p12080	525	1	825	1	900	1	1050	1	1200	1
p12048	375	1								
p12050	375	1								

Pipe Name	Existing Dia.	number of pipes	Upgraded Diameter 2y	no.	10y	no.	20y	no.	100y	no.
p8272	375	1								
p8274	375	1	600	1	675	1	750	1	825	1
p8276	375	1	600	1	675	1	750	1	825	1
p9000	375	1								
p9010	450	1			525	1	600	1	600	1
p9012	525	1					600	1	600	1
p9014	525	1			600	1	600	1	675	1
p9020	525	1	675	1	825	1	1050	1	1200	1
p9022	525	1	750	1	900	1	1050	1	1200	1
p9024	525	1	750	1	900	1	1050	1	1200	1
p9026	600	1	750	1	900	1	1050	1	1200	1
p9068	825	1	1500	1	1800	1	1650	1	1800	1
p9070	825	1	1500	1	1800	1	1650	1	1800	1
p9072	825	1	1500	1	1800	1	1800	1	1950	1
p9074	825	1	1500	1	1800	1	1800	1	1950	1
p9076	825	1	1500	1	1800	1	1800	1	1950	1
p9078	825	1	1500	1	1950	1	1800	1	1950	1
p9080	825	1	1500	1	1950	1	1800	1	2100	1
p9124	1050	1	1650	1	1950	1	2550	1	2550	1
p9128	2.4W x 1H	1	not		not		not		not	
p9130	1200	1	1950	1	2550	1	2550	1	2550	1
p9132	1.2W x 0.5H	1	2550	1	2550	1	2550	1	2550	1
p9168	1350	1	1650	1	2100	1	2250	1	2250	1
p9172	1350	1	2100	1	2550	1	2550	1	2550	1
p9194	1350	1	2250	1	2550	1	2550	1	2550	2
p9196	1350	1	2250	1	2550	1	2550	1	2550	1
p9198	1350	1	2250	1	2550	1	2550	1	2550	2
p9208	1350	1	2250	1	2550	1	2550	1	2550	1
p9210	1350	1	2250	1	2550	1	2550	1	2550	1
p9001	375	1								
p9002	375	1							450	1
p9004	375	1			525	1	525	1	600	1
p9006	375	1								
p9008	450	1			525	1	525	1	600	1
p9016	375	1	450	1	525	1	600	1	600	1
p9018	525	1					600	1	675	1
p9028	375	1	600	1	600	1	750	1	675	1
p9030	375	1	525	1	675	1	600	1	675	1
p9032	1.2W x 0.9H	1	525	1	675	1	675	1	750	1
p9034	675	1	1200	1	1200	1	1200	1	1200	1
p9036	675	1	1200	1	1200	1	1200	1	1350	1
p9040	675	1	1200	1	1200	1	1200	1	1350	1
p9054	0.9W x 0.6H	1	825	1	1200	1	1350	1	1350	1
p9056	675	1	825	1	1200	1	1050	1	1350	1
p9038	450	1								
p9042	375	1			450	1	450	1	450	1
p9044	375	1	600	1	750	1	675	1	825	1
p9046	450	1	600	1	750	1	900	1	1200	1
p9048	450	1	675	1	825	1	900	1	1200	1
p9050	450	1	675	1	825	1	900	1	1200	1
p9052	450	1	825	1	1050	1	1200	1	1200	1
p9058	225	1	450	1	525	1	525	1	600	1
p9060	375	1								
p9064	375	1	525	1	675	1	675	1	750	1
p9066	375	1	525	1	675	1	675	1	750	1
p9062	375	1	525	1	675	1	675	1	750	1
p9082	150	1	225	1	300	1	300	1	375	1
p9084	300	1							375	1
p9086	300	1	375	1	525	1	600	1	675	1
p9088	300	1	450	1	675	1	675	1	750	1
p9090	300	1	450	1	675	1	675	1	825	1
p9092	300	1	450	1	675	1	675	1	825	1
p9094	375	1	525	1	750	1	675	1	825	1
p9096	300	1	375	1	450	1	525	1	525	1
p9098	300	1	600	1	750	1	825	1	900	1
p9102	300	1	600	1	750	1	825	1	900	1
p9104	375	1	600	1	750	1	825	1	900	1
p9108	375	1	600	1	750	1	825	1	900	1
p9114	375	1	750	1	1050	1	1200	1	1200	1
p9116	375	1	825	1	1050	1	1200	1	1200	1
p9122	0.45W x 0.4H	1	900	1	1050	1	1200	1	1350	1
p9100	300	1			375	1	450	1	450	1
p9106	375	1	600	1	675	1	600	1	675	1
p9110	300	1	525	1	675	1	675	1	750	1
p9112	300	1	675	1	825	1	750	1	825	1
p9118	300	1	675	1	900	1	825	1	1050	1
p9120	300	1	750	1	900	1	1050	1	1050	1
p9126	375	1								
p9134	375	1			450	1	450	1	525	1
p9136	375	1	450	1	525	1	600	1	675	1
p9140	375	1	525	1	600	1	600	1	675	1
p9144	375	1	525	1	675	1	750	1	750	1
p9150	375	1	600	1	675	1	750	1	825	1
p9152	375	1	675	1	825	1	900	1	1050	1
p9158	375	1	675	1	825	1	900	1	1050	1
p9160	450	1	750	1	900	1	1050	1	1050	1
p9166	450	1	1050	1	1200	1	1200	1	1350	1
p9138	375	1								
p9142	300	1							375	1
p9146	300	1	600	1	675	1	750	1	825	1
p9148	300	1	600	1	675	1	750	1	825	1
p9154	300	1	375	1	525	1	525	1	600	1
p9156	300	1	525	1	675	1	750	1	825	1
p9162	300	1	600	1	750	1	825	1	900	1
p9164	300	1	600	1	750	1	825	1	900	1
p9170	225	1	450	1	525	1	600	1	600	1
p9174	300	1	525	1	675	1	750	1	825	1
p9176	300	1	675	1	900	1	900	1	1050	1
p9178	300	1	675	1	900	1	900	1	1050	1

Pipe Name	Existing Dia.	number of pipes	Upgraded Diameter 2y	no.	10y	no.	20y	no.	100y	no.
p12066	375	1								
p12070	375	1							450	1
p12072	375	1							450	1
p12084	375	1								
p12086	450	1								
p12090	300	1	375	1	450	1	525	1	525	1
p12092	375	1			450	1	525	1	525	1
p12094	375	1			450	1	525	1	525	1
p12096	525	1								
p12098	525	1								
p12102	525	1							600	1
p12104	525	1	600	1	750	1	675	1	750	1
p12106	525	1	600	1	750	1	675	1	750	1
p12110	750	1							825	1
p12118	750	1	825	1	1050	1	1050	1	1200	1
p12120	750	1	825	1	1050	1	1050	1	1200	1
p12124	900	1			1050	1	1050	1	1200	1
p12132	900	1			1050	1	1200	1	1350	1
p12134	900	1			1050	1	1200	1	1350	1
p12140	1050	1					1200	1	1350	1
p12142	1050	1					1200	1	1350	1
p12100	375	1			450	1	525	1	525	1
p12108	375	1			450	1	450	1	450	1
p12112	375	1	450	1	600	1	600	1	675	1
p12114	375	1	600	1	750	1	750	1	825	1
p12116	375	1	600	1	825	1	825	1	825	1
p12122	375	1			450	1	450	1	525	1
p12126	300	1	525	1	675	1	675	1	750	1
p12128	375	1	525	1	675	1	675	1	750	1
p12130	375	1	525	1	675	1	675	1	750	1
p12136	375	1								
p12138	525	1								
p13000	375	1	450	1	600	1	600	1	675	1
p13002	375	1	450	1	600	1	600	1	675	1
p13004	375	1	525	1	675	1	600	1	675	1
p13006	375	1	600	1	675	1	750	1	825	1
p13012	375	1	600	1	750	1	825	1	900	1
p13014	375	1	675	1	750	1	825	1	900	1
p13018	375	1	750	1	750	1	900	1	900	1
p13020	375	1	750	1	825	1	900	1	1050	1
p13032	2.1W x 0.9H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p13034	2.1W x 0.9H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p13054	1050	1	1500	1	1500	1	1650	1	1500	1
p13056	1050	1	1500	1	1500	1	1650	1	1500	1
p13070	900	1	1500	1	1500	1	1650	1	1800	1
p13072	900	1	1500	1	1500	1	1650	1	1800	1
p13074	900	1	1500	1	1500	1	1650	1	1800	1
p13008	375	1					450	1	450	1
p13010	375	1								
p13016	375	1								
p13022	375	1	525	1	675	1	675	1	750	1
p13024	450	1	525	1	675	1	675	1	750	1
p13026	375	1								
p13028	450	1								
p13030	450	1								
p13036	225	1			300	1	300	1	375	1
p13038	300	1			375	1	375	1	375	1
p13040	300	1	375	1	450	1	450	1	525	1
p13042	450	1							525	1
p13044	450	1							525	1
p13046	450	1							525	1
p13050	450	1	525	1	675	1	750	1	825	1
p13052	450	1	525	1	675	1	750	1	900	1
p13048	375	1	525	1	675	1	750	1	750	1
p13058	375	1								
p13060	375	1								
p13062	375	1								
p13066	450	1	600	1	825	1	900	1	1050	1
p13068	450	1	600	1	825	1	900	1	1050	1
p13064	225	1	600	1	825	1	900	1	1050	1
p13084	450	1	525	1	600	1	675	1	600	1
p13088	675	1								
p13090	675	1							750	1
p13092	450	1	525	1	600	1	675	1	750	1
p13094	450	1	525	1	600	1	675	1	750	1
p13086	375	1								
p14000	375	1								
p14002	375	1								
p14004	375	1								
p14006	375	1								
p14008	375	1			525	1	450	1	525	1
p14010	375	1	450	1	525	1	525	1	600	1
p14014	375	1	525	1	675	1	675	1	750	1
p14016	375	1	525	1	675	1	675	1	750	1
p14018	375	1	600	1	750	1	825	1	825	1
p14022	375	1	675	1	825	1	900	1	900	1
p14024	375	1	750	1	900	1	1050	1	1050	1
p14025	675	1	1050	1	1200	1	1350	1	1500	1
p14026	675	1	1050	1	1350	1	1500	1	1650	1
pS22003	1200	1	1350	1	1650	1	1800	1	2250	1
p14034	2.4W x 1H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14012	375	1			450	1	450	1	525	1
p14020	375	1								
p14028	675	1	900	1	1200	1	1350	1	1500	1
p14032	2.4W x 1.4H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14030	2.4W x 1.8H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14092	2.4W x 1.4H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14102	2.4W x 1.4H	1	not upgraded		not upgraded		not upgraded		not upgraded	
pWMA98	2.4W x 1.4H	1	not upgraded		not upgraded		not upgraded		not upgraded	

Pipe Name	Existing Dia.	number of pipes	Upgraded Diameter 2y	no.	10y	no.	20y	no.	100y	no.
p9186	525	1	825	1	1200	1	1050	1	1200	1
p9190	525	1	825	1	1200	1	1200	1	1350	1
p9192	525	1	900	1	1200	1	1350	1	1500	1
p9180	375	1	525	1	675	1	675	1	825	1
p9182	375	1	600	1	675	1	750	1	825	1
p9184	525	1	600	1	750	1	825	1	900	1
p9188	300	1	375	1	450	1	450	1	525	1
p9200	225	1	300	1	375	1	450	1	450	1
p9206	375	1					450	1	450	1
p9202	300	1								
p9204	225	1								
p10000	375	1	450	1	600	1	600	1	525	1
p10006	450	1			600	1	600	1	675	1
p10008	450	1			600	1	600	1	675	1
p10012	450	1	525	1	675	1	750	1	675	1
p10024	525	1	750	1	900	1	1050	1	1200	1
p10026	525	1	750	1	900	1	1050	1	1200	1
p10028	900	1					1200	1	1350	1
p10030	900	1			1050	1	1200	1	1350	1
p10032	1.2W x 0.5H	1	750	1	1050	1	1200	1	1350	1
p10076	750	1	1350	1	1500	1	1500	1	1650	1
p10078	750	1	1350	1	1650	1	1500	1	1650	1
p10080	750	1	1350	1	1650	1	1650	1	1650	1
p10082	750	1	1350	1	1650	1	1650	1	1800	1
p10084	0.8W x 0.5H	1	1350	1	1650	1	1650	1	1950	1
p10086	0.9W x 0.6H	1	1350	1	1650	1	1650	1	1950	1
p10090	0.9W x 0.6H	1	1350	1	1650	1	1650	1	2100	1
p10134	0.9W x 0.6H	1	1800	1	1950	1	2400	1	2550	1
p10136	0.9W x 0.6H	1	1800	1	1950	1	2400	1	2550	1
p10138	0.9W x 0.6H	1	1800	1	1950	1	2400	1	2550	1
p10140	0.9W x 0.6H	1	1800	1	1950	1	2400	1	2550	1
p10144	0.9W x 0.6H	1	1800	1	1950	1	2400	1	2550	1
p10156	0.9W x 0.6H	1	1800	1	2100	1	2550	1	2550	1
p10158	0.9W x 0.6H	1	1800	1	2100	1	2550	1	2550	1
p10176	0.9W x 0.6H	1	1800	1	2250	1	2550	1	2700	1
p10180	1.2W x 0.9H	1	1800	1	2250	1	2550	1	2700	1
p10184	1.2W x 0.9H	1	1800	1	2250	1	2550	1	2700	1
p10211	2.1W x 0.9H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10213	2.1W x 0.9H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10214	2.1W x 0.9H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10215	2.1W x 0.9H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10216	2.1W x 0.9H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10218	2.1W x 0.9H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10228	2.4W x 1.2H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10229	2.4W x 1.2H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10230	2.4W x 1.2H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10231	2.4W x 1.2H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10232	2.4W x 1.2H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10240	2.4W x 1.2H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10294	2.4W x 1.4H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10296	1.2W x 0.9H	1	2700	1	2700	1	2700	1	2700	2
p10300	1.2W x 0.9H	1	2700	1	2700	1	2700	1	2700	1
p10304	1.2W x 0.9H	1	2700	1	2700	1	2700	1	2700	1
p10308	900	1	2700	1	2700	1	2700	1	2700	2
p10312	1.2W x 0.9H	1	2700	1	2700	1	2700	1	2700	1
p10314	1.2W x 0.9H	1	2700	1	2700	1	2700	1	2700	1
p10316	1.2W x 0.9H	1	2700	1	2700	1	2700	1	2700	1
p10320	1.2W x 0.9H	1	2700	1	2700	1	2700	1	2700	1
p10332	1.2W x 0.9H	1	2700	1	2700	1	2700	1	2700	1
p10233	2.4W x 1.2H	1	not		not		not		not	
p10476	1200	1	2700	1	2700	2	2700	2	2700	2
p10480	2.4W x 1.2H	1	not		not		not		not	
p10492	2.4W x 1.2H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10498	2.4W x 1.2H	1	not		not		not		not	
p10504	2.4W x 1.2H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10506	2.4W x 1.4H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10512	2.4W x 1.4H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10520	2.4W x 1.4H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10522	2.4W x 1.4H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p10001	375	1	450	1	600	1	600	1	675	1
p10002	375	1	450	1	600	1	600	1	525	1
p10003	375	1			525	1	525	1	600	1
p10004	375	1								
p10005	375	1								
p10007	375	1	525	1	600	1	525	1	600	1
p10220	375	1	525	1	600	1	675	1	675	1
p10221	450	1	525	1	600	1	675	1	675	1
p10222	600	1			675	1	675	1	750	1

Pipe Name	Existing Dia.	number of pipes	Upgraded Diameter 2y	no.	10y	no.	20y	no.	100y	no.
p14108	2.4W x 1.8H	3	not upgraded		not upgraded		not upgraded		not upgraded	
p14110	2.1W x 0.9H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14112	2.1W x 0.9H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14035	525	1	675	1	825	1	900	1	1050	1
p14036	525	1	750	1	900	1	1050	1	1050	1
p14038	900	1					1050	1	1050	1
p14040	900	1					1050	1	1050	1
p14042	150	1	1050	1	1200	1	1350	1	1500	1
pWMA78	375	1	1050	1	1350	1	1500	1	1650	1
pWMA76	750	1	1050	1	1350	1	1500	1	1650	1
p14048	750	1	1050	1	1350	1	1500	1	1650	1
p14088	1050	1	1200	1	1500	1	1650	1	1800	1
p14090	1050	1	1200	1	1500	1	1650	1	1800	1
p14046	600	1								
p14052	375	1								
p14054	375	1								
p14055	450	1	600	1	750	1	825	1	900	1
p14056	450	1	675	1	750	1	900	1	900	1
p14057	1050	1								
p14058	1050	1								
p14059	1050	1								
p14060	1050	1					1200	1	1200	1
p14061	1050	1			1200	1	1200	1	1500	1
p14062	1050	1			1200	1	1200	1	1500	1
p14063	1050	1			1200	1	1200	1	1500	1
p14064	1050	1			1200	1	1200	1	1500	1
p14065	1050	1			1200	1	1200	1	1500	1
p14066	375	1	525	1	675	1	675	1	750	1
p14067	375	1			450	1	525	1	525	1
p14068	375	1			450	1	525	1	525	1
p14069	375	1	525	1	600	1	525	1	675	1
p14070	375	1	450	1	525	1	600	1	525	1
p14071	375	1	675	1	825	1	750	1	825	1
p14072	450	1	675	1	825	1	900	1	900	1
p14073	450	1	675	1	825	1	900	1	1050	1
p14074	450	1			525	1	525	1	600	1
p14075	300	1	525	1	525	1	675	1	600	1
p14076	300	1								
p14077	375	1								
p14078	375	1			450	1	450	1	450	1
p14079	375	1	600	1	750	1	675	1	750	1
p14080	375	1	600	1	750	1	675	1	750	1
p14081	375	1	600	1	750	1	750	1	825	1
p14084	525	1	675	1	750	1	825	1	900	1
p14085	750	1			900	1	1050	1	1050	1
p14086	750	1	1650	1	1950	1	2250	1	2100	1
p14087	1.2W x 0.9H	1	2100	1	2550	1	2550	1	2550	1
p14088	2.1W x 0.9H	1								
p14089	375	1								
p14090	375	1	525	1	600	1	675	1	675	1
p14091	375	1	525	1	600	1	675	1	675	1
p14092	375	1								
p14093	375	1	1200	1	1650	1	1800	1	1950	1
p14094	375	1	1200	1	1650	1	1800	1	1950	1
p14095	375	1	1350	1	1800	1	1950	1	2100	1
p14096	375	1	1350	1	1800	1	1950	1	2100	1
p14097	375	1	1500	1	1950	1	2100	1	2100	1
p14098	1200	1								
p14099	1200	1							1350	1
p14100	1200	1							1350	1
p14101	1200	1							1350	1
p14102	1200	1							1350	1
p14103	2.4W x 1.2H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14104	150	1								
p14105	2.4W x 1.8H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14106	2.4W x 1.8H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14107	2.4W x 1.8H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14108	2.4W x 1.8H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14109	2.4W x 1.8H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14110	375	1	525	1	675	1	675	1	750	1
p14111	375	1	1050	1	1200	1	1350	1	1350	1
p14112	450	1	1050	1	1200	1	1350	1	1350	1
p14113	375	1	675	1	825	1	900	1	1050	1
p14114	300	1			375	1	375	1	450	1
p14115	300	1	375	1	450	1	450	1	525	1
p14116	300	1	375	1	450	1	525	1	525	1
p14117	300	1	450	1	525	1	600	1	600	1
p14118	450	1	600	1	675	1	675	1	750	1

Pipe	Existing	number	Upgraded Diameter							
Name	Dia.	of pipes	2y	no.	10y	no.	20y	no.	100y	no.
p10223	750	1								
p10224	750	1					825	1	1050	1
p10225	2.1W x 0.9H	1	not		not		not		not	
p10226	2.1W x 0.9H	1	not		not		not		not	
p10227	750	1	1500	1	1500	1	1500	1	1500	1
p10009	375	1								
p10010	375	1	450	1	525	1	600	1	600	1
p10011	375	1			450	1	450	1	525	1
p10013	375	1								
p10014	375	1	450	1	525	1	600	1	525	1
p10016	525	1			675	1	675	1	825	1
p10018	525	1			675	1	675	1	825	1
p10015	375	1	450	1	525	1	600	1	525	1
p10017	375	1								
p10019	375	1					450	1	450	1
p10020	375	1								
p10021	225	1	300	1	375	1	450	1	450	1
p10023	375	1					450	1	450	1
p10022	375	1	450	1	525	1	600	1	600	1
p10034	375	1			450	1	450	1	525	1
p10036	375	1			450	1	450	1	525	1
p10042	450	1							525	1
p10062	450	1	750	1	1050	1	1200	1	1200	1
p10064	450	1	750	1	1050	1	1200	1	1350	1
p10068	450	1	750	1	1050	1	1200	1	1350	1
p10070	450	1	825	1	1050	1	1200	1	1350	1
p10072	450	1	825	1	1200	1	1350	1	1350	1
p10035	375	1								
p10037	375	1								
p10038	375	1								
p10040	375	1					450	1	450	1
p10044	300	1								
p10048	300	1					375	1	375	1
p10052	375	1							450	1
p10046	300	1							375	1
p10050	300	1			375	1	375	1	375	1
p10054	300	1	375	1	450	1	450	1	525	1
p10056	300	1	450	1	525	1	525	1	600	1
p10058	300	1	450	1	525	1	600	1	675	1
p10060	300	1	600	1	600	1	750	1	675	1
p10066	450	1								
p10074	375	1			450	1	525	1	600	1
p10077	375	1								
p10088	375	1	525	1	600	1	675	1	750	1
p10092	375	1					450	1	450	1
p10094	375	1								
p10096	375	1								
p10102	375	1	525	1	525	1	675	1	600	1
p10104	375	1	525	1	600	1	675	1	600	1
p10108	375	1	600	1	750	1	750	1	900	1
p10112	375	1	600	1	750	1	750	1	900	1
p10114	600	1	750	1	900	1	825	1	1050	1
p10116	600	1	750	1	1050	1	900	1	1050	1
p10126	600	1	825	1	1200	1	1200	1	1200	1
p10128	600	1	900	1	1200	1	1200	1	1350	1
p10130	600	1	1050	1	1350	1	1350	1	1350	1
p10098	300	1	525	1	525	1	675	1	600	1
p10100	300	1					375	1	375	1
p10106	300	1	600	1	675	1	600	1	675	1
p10110	300	1								
p10117	450	1			525	1	525	1	600	1
p10118	450	1			525	1	525	1	600	1
p10120	525	1							600	1
p10172	300	1	525	1	525	1	600	1	750	1
p10174	375	1	1350	1	1650	1	1800	1	1950	1
p10122	600	1								
p10124	600	1							675	1
p10132	375	1	450	1	600	1	600	1	675	1
p10142	300	1	375	1	450	1	450	1	525	1
p10146	375	1	600	1	675	1	825	1	825	1
p10148	375	1								
p10150	375	1	450	1	525	1	525	1	600	1
p10152	450	1			525	1	525	1	600	1
p10154	450	1	525	1	600	1	525	1	675	1
p10160	300	1	375	1	525	1	525	1	600	1
p10164	375	1	825	1	1200	1	1050	1	1200	1
p10168	375	1	900	1	1350	1	1200	1	1200	1
p10162	300	1	825	1	1200	1	1050	1	1200	1
p10166	300	1	600	1	600	1	675	1	750	1
p10170	300	1	525	1	675	1	750	1	825	1
p10178	0.3W x 0.225H	1	450	1	525	1	600	1	600	1
p10182	225	1								
p10186	300	1	450	1	525	1	600	1	600	1
p10190	375	1	450	1	525	1	600	1	600	1
p10192	375	1	525	1	675	1	750	1	825	1
p10194	375	1	600	1	750	1	825	1	900	1
p10196	375	1	750	1	750	1	825	1	1050	1
p10198	450	1	750	1	900	1	900	1	1050	1
p10204	450	1	825	1	1050	1	1050	1	1200	1
p10206	450	1	825	1	1050	1	1200	1	1200	1
p10208	450	1	825	1	1200	1	1350	1	1200	1
p10210	450	1	900	1	1350	1	1350	1	1350	1
p10188	300	1			375	1	375	1	450	1
p10200	375	1			450	1	525	1	525	1
p10202	0.9W x 0.6H	1	450	1	525	1	525	1	600	1
p10217	375	1			450	1	525	1	525	1
p10234	375	1					450	1	450	1
p10236	375	1					450	1	450	1
p10238	375	1	600	1	750	1	675	1	825	1
p10242	300	1	450	1	525	1	525	1	600	1
p10244	300	1	450	1	600	1	675	1	675	1
p10246	300	1	525	1	675	1	675	1	750	1
p10248	300	1	600	1	750	1	825	1	825	1
p10250	375	1	600	1	750	1	825	1	825	1
p10252	375	1	600	1	750	1	825	1	900	1

Pipe	Existing	number	Upgraded Diameter							
Name	Dia.	of pipes	2y	no.	10y	no.	20y	no.	100y	no.
p14119	450	1	600	1	750	1	825	1	900	1
p14120	450	1	750	1	900	1	900	1	1050	1
p14121	1.2W x 0.5H	1	900	1	1200	1	1200	1	1350	1
p14122	525	1	1050	1	1050	1	1050	1	1200	1
p14123	525	1	1050	1	1050	1	1200	1	1350	1
p14124	525	1	1050	1	1050	1	1200	1	1350	1
p14125	525	1	1050	1	1350	1	1500	1	1650	1
p14126	300	1	450	1	600	1	600	1	675	1
p14127	300	1			450	1	450	1	525	1
p14128	300	1	375	1	450	1	450	1	525	1
p14129	375	1			450	1	450	1	525	1
p14130	375	1	525	1	675	1	750	1	750	1
p14131	450	1	675	1	750	1	825	1	900	1
p14132	450	1	750	1	825	1	1050	1	1200	1
p14133	450	1	750	1	900	1	1050	1	1200	1
p14134	300	1	375	1	450	1	450	1	525	1
p14135	300	1	375	1	450	1	450	1	525	1
p14136	375	1	525	1	675	1	675	1	750	1
p14137	375	1	900	1	1200	1	1350	1	1500	1
p14138	2.4W x 1.8H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14139	1.2W x 0.9H	1	100	1	100	1	100	1	100	1
p14140	1.2W x 0.9H	1	100	1	100	1	100	1	100	1
p14141	1.2W x 0.9H	1	525	1	675	1	675	1	750	1
p14142	900	1	1200	1	1200	1	1200	1	1200	1
p14143	1050	1	1200	1	1200	1	1200	1	1350	1
p14144	1050	1	1200	1	1200	1	1350	1	1500	1
p14145	1050	1	1200	1	1200	1	1350	1	1500	1
p14146	1200	1			1350	1	1350	1	1500	1
p14147	1200	1			1350	1	1350	1	1500	1
p14148	1200	1			1500	1	1350	1	1500	1
p14149	1350	1			1500	1	1500	1	1650	1
p14150	1350	1			1500	1	1500	1	1650	1
p14151	1350	1			1500	1	1500	1	1650	1
p14152	1350	1			1500	1	1500	1	1650	1
p14153	1350	1			1500	1	1500	1	1650	1
p14154	1350	1			1500	1	1500	1	1650	1
p14155	2.1W x 0.9H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14156	1350	1	1500	1	1500	1	1500	1	1500	1
p14157	375	1								
p14158	375	1			450	1	525	1	525	1
p14159	375	1					450	1	450	1
p14160	375	1					450	1	450	1
p14161	375	1								
p14162	375	1					450	1	450	1
p14163	375	1					450	1	450	1
p14164	375	1								
p14165	1200	1								
p14166	375	1							450	1
p14167	375	1					450	1	450	1
p14168	375	1			450	1	450	1	525	1
p14169	375	1								
p14170	375	1								
p14171	600	1								
p14172	600	1								
p14173	0.9W x 0.6H	1	525	1	675	1	675	1	675	1
p14174	0.9W x 0.6H	1	900	1	1200	1	1200	1	1350	1
p14175	0.9W x 0.6H	1	1050	1	1200	1	1200	1	1350	1
p14176	0.9W x 0.6H	1	1050	1	1200	1	1200	1	1350	1
p14177	0.9W x 0.6H	1	1050	1	1200	1	1200	1	1350	1
p14178	0.9W x 0.6H	1	1050	1	1200	1	1200	1	1350	1
p14179	0.9W x 0.6H	1	1050	1	1200	1	1200	1	1350	1
p14180	750	1	900	1	1200	1	1350	1	1350	1
p14181	750	1	1200	1	1500	1	1500	1	1800	1
p14182	900	1	1200	1	1500	1	1500	1	1800	1
p14183	900	1	1200	1	1500	1	1500	1	1800	1
p14184	300	1	525	1	525	1	675	1	600	1
p14185	300	1	525	1	675	1	675	1	675	1
p14186	300	1	750	1	900	1	1200	1	1050	1
p14187	300	1	825	1	1200	1	1200	1	1350	1
p14188	375	1	900	1	1200	1	1200	1	1350	1
p14189	300	1	375	1	450	1	450	1	525	1
p14190	300	1								
p14191	300	1								
p14192	300	1	600	1	750	1	675	1	750	1
p14193	300	1	600	1	600	1	675	1	750	1
p14194	300	1	375	1	450	1	525	1	525	1
p14195	375	1								
p14196	450	1								
p14197	450	1								
p14198	450	1	675	1	900	1	1050	1	1050	1
p14199	525	1	675	1	900	1	1050	1	1050	1
p14200	525	1	675	1	900	1	1050	1	1050	1
p14201	300	1	750	1	900	1	1050	1	1050	1
p14202	2.4W x 1.8H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14203	150	1	2100	1	2550	1	2550	1	2700	2
p14204	150	1	2550	1	2550	1	2550	2	2700	2
p14205	675	1	2550	1	2550	2	2550	2	2700	2
p14206	675	1	2550	1	2550	1	2550	2	2700	2
p14207	2.4W x 1.4H	1	not upgraded		not upgraded		not upgraded		not upgraded	
p14208	375	1	525	1	675	1	750	1	825	1
p14209	375	1	525	1	675	1	750	1	825	1
p14210	525	1	600	1	675	1	750	1	825	1
p14211	525	1	750	1	825	1	825	1	1050	1
p14212	525	1	750	1	900	1	1050	1	1050	1
p14213	375	1	675	1	825	1	825	1	900	1
p14214	375	1	675	1	825	1	825	1	900	1
p14215	375	1								
p14216	375	1	600	1	750	1	825	1	900	1
p14217	375	1	600	1	750	1	825	1	900	1
p14218	375	1	675	1	825	1	825	1	1050	1
p14219	600	1	675	1	825	1	825	1	1050	1
p14220	600	1	900	1	1050	1	1050	1	1350	1
p14221	600	1	1050	1	1350	1	1350	1	1500	1
p14222	375	1								
p14223	375	1								

Pipe	Existing	number	Upgraded Diameter							
Name	Dia.	of pipes	2y	no.	10y	no.	20y	no.	100y	no.
p10254	375	1	600	1	750	1	825	1	900	1
p10256	375	1	600	1	750	1	825	1	900	1
p10266	450	1	600	1	750	1	825	1	900	1
p10270	450	1	600	1	750	1	825	1	900	1
p10276	450	1	600	1	750	1	825	1	900	1
p10278	450	1	600	1	750	1	825	1	900	1
p10286	450	1	675	1	750	1	825	1	900	1
p10288	450	1	750	1	825	1	1050	1	1050	1
p10290	675	1	750	1	900	1	1050	1	1200	1
p10292	675	1	900	1	1050	1	1050	1	1200	1
p10258	375	1								
p10264	450	1								
p10260	375	1								
p10262	375	1								
p10268	375	1								
p10272	375	1							450	1
p10274	375	1			450	1	525	1	525	1
p10280	375	1								
p10282	225	1	300	1	375	1	450	1	450	1
p10284	225	1	375	1	450	1	450	1	450	1
p10298	375	1	525	1	675	1	675	1	750	1
p10302	375	1	450	1	600	1	600	1	675	1
p10306	375	1	450	1	600	1	600	1	675	1
p10310	375	1	450	1	525	1	600	1	525	1
p10318	375	1	450	1	600	1	525	1	600	1
p10322	375	1	450	1	600	1	600	1	675	1
p10324	450	1			600	1	600	1	675	1
p10328	450	1	525	1	600	1	675	1	675	1
p10330	450	1	525	1	675	1	675	1	750	1
p10326	375	1								
p10348	375	1	450	1	525	1	525	1	600	1
p10350	375	1	525	1	750	1	825	1	750	1
p10358	450	1	675	1	750	1	825	1	900	1
p10362	450	1	675	1	750	1	825	1	900	1
p10366	450	1	675	1	825	1	1050	1	1050	1
p10370	450	1	750	1	900	1	1050	1	1200	1
p10374	450	1	750	1	900	1	1050	1	1350	1
p10398	600	1	900	1	1200	1	1200	1	1350	1
p10400	600	1	1050	1	1200	1	1350	1	1350	1
p10406	600	1	1050	1	1200	1	1350	1	1350	1
p10408	600	1	1050	1	1350	1	1350	1	1500	1
p10414	600	1	1050	1	1350	1	1350	1	1500	1
p10416	750	1	1200	1	1500	1	1500	1	1650	1
p10422	750	1	1350	1	1650	1	1650	1	1950	1
p10426	750	1	1500	1	1950	1	2100	1	2400	1
p10438	1200	1	1500	1	1950	1	2100	1	2400	1
p10442	1200	1	1650	1	2100	1	2100	1	2400	1
p10452	1200	1	1650	1	2100	1	2100	1	2400	1
p10456	1200	1	1650	1	2100	1	2100	1	2400	1
p10458	1200	1	1650	1	2100	1	2100	1	2400	1
p10468	1200	1	1650	1	2100	1	2100	1	2550	1
p10472	1200	1	1650	1	2100	1	2250	1	2550	1
p10474	1200	1	1650	1	2100	1	2250	1	2550	1
p10352	225	1	300	1	300	1	375	1	375	1
p10356	300	1			375	1	450	1	450	1
p10354	225	1	300	1	300	1	375	1	375	1
p10360	375	1	450	1	600	1	600	1	675	1
p10364	375	1	450	1	525	1	600	1	525	1
p10368	375	1								
p10372	375	1			525	1	525	1	600	1
p10376	300	1								
p10378	450	1								
p10382	450	1			525	1	525	1	600	1
p10384	450	1			525	1	525	1	600	1
p10386	450	1	525	1	600	1	675	1	675	1
p10390	450	1	600	1	675	1	750	1	825	1
p10392	600	1			750	1	750	1	825	1
p10396	600	1	750	1	750	1	825	1	1050	1
p10380	450	1					525	1	525	1
p10388	375	1								
p10394	375	1								
p10402	375	1			450	1	525	1	525	1
p10404	375	1	675	1	825	1	1050	1	1050	1
p10410	375	1	525	1	675	1	750	1	825	1
p10412	375	1	675	1	825	1	825	1	900	1
p10418	375	1			450	1	525	1	525	1
p10420	375	1			450	1	525	1	525	1
p10424	375	1	450	1	525	1	600	1	525	1
p10428	375	1	450	1	525	1	525	1	600	1
p10430	450	1			525	1	525	1	600	1
p10434	450	1	525	1	675	1	675	1	750	1
p10436	450	1	525	1	675	1	675	1	750	1
p10432	375	1			525	1	525	1	600	1
p10440	300	1	525	1	525	1	675	1	750	1
p10444	300	1							375	1
p10450	300	1	375	1	450	1	525	1	600	1
p10446	300	1	375	1	450	1	525	1	600	1
p10448	300	1	375	1	450	1	525	1	600	1
p10454	300	1	375	1	525	1	525	1	600	1
p10466	450	1	600	1	600	1	675	1	750	1
p10470	300	1	375	1	450	1	525	1	525	1
p10478	375	1							450	1
p10482	300	1	600	1	750	1	675	1	750	1
p10484	300	1	600	1	750	1	825	1	750	1
p10486	375	1	600	1	750	1	825	1	750	1
p10490	375	1	750	1	750	1	825	1	1050	1
p10488	300	1	375	1	450	1	525	1	600	1
p10494	375	1	525	1	525	1	675	1	750	1
p10496	375	1	600	1	675	1	750	1	825	1
p10500	375	1								
p10502	300	1							375	1
p10508	375	1	450	1	525	1	600	1	525	1
p10510	375	1	675	1	825	1	1050	1	1200	1
p10514	375	1								
p10516	375	1					450	1	450	1
p10518	375	1					525	1	600	1
p10528	300	1	450	1	600	1	525	1	675	1
p10530	300	1	675	1	825	1	1050	1	1050	1

Pipe	Existing	number	Upgraded Diameter							
Name	Dia.	of pipes	2y	no.	10y	no.	20y	no.	100y	no.
p14224	375	1								
p14225	375	1	525	1	675	1	750	1	825	1
p14226	375	1	525	1	600	1	675	1	675	1
p14227	375	1	525	1	600	1	675	1	675	1
p14228	375	1	525	1	675	1	675	1	750	1
p14229	375	1	675	1	825	1	900	1	1050	1
p14230	375	1	675	1	825	1	900	1	1050	1
p14231	375	1							450	1
p14232	375	1	525	1	675	1	675	1	750	1
p14233	375	1	675	1	675	1	750	1	825	1
p14234	375	1	675	1	825	1	825	1	825	1
p14235	450	1	675	1	825	1	900	1	1050	1
p14236	600	1	675	1	900	1	900	1	1050	1
p14237	600	1	825	1	1050	1	1050	1	1200	1
p14238	600	1	825	1	1050	1	1050	1	1200	1
p14239	375	1	525	1	600	1	525	1	675	1
p14240	375	1	525	1	525	1	675	1	750	1
p14241	375	1	525	1	675	1	675	1	750	1
p14242	375	1								
p14243	300	1	600	1	600	1	675	1	750	1
p14244	375	1	600	1	600	1	675	1	750	1
p14245	375	1	600	1	600	1	675	1	750	1
p14246	450	1	900	1	900	1	1200	1	1200	1
p14247	450	1	900	1	1050	1	1200	1	1200	1
p14248	450	1	900	1	1050	1	1200	1	1200	1
p14249	525	1	900	1	1050	1	1200	1	1200	1
p14250	600	1	900	1	1050	1	1200	1	1200	1
p14251	525	1	900	1	1050	1	1200	1	1200	1
p14252	600	1	1050	1	1350	1	1350	1	1500	1
p14253	600	1	1350	1	1500	1	1350	1	1650	1
p14254	600	1	1350	1	1650	1	1350	1	1800	1
p14255	150	1	1350	1	1650	1	1500	1	1800	1
p14256	3.2W x 1.6H	3	not upgraded		not upgraded		not upgraded		not upgraded	
p14257	2.4W x 1.8H	4	not upgraded		not upgraded		not upgraded		not upgraded	
p14258	375	1								
p14259	375	1								
p14260	375	1			450	1	450	1	525	1
p14261	375	1			450	1	450	1	525	1
p14262	375	1	525	1	675	1	675	1	750	1
p14263	450	1	600	1	750	1	825	1	750	1
p14264	450	1	675	1	825	1	900	1	1050	1
p14265	450	1	900	1	900	1	1200	1	1200	1
p14266	375	1			450	1	525	1	525	1
p14267	375	1			450	1	450	1	525	1
p14268	375	1			450	1	450	1	450	1
p14269	375	1								
p14270	375	1								
p14271	525	1			600	1	600	1	675	1
p14272	375	1	525	1	525	1	675	1	750	1
p14273	375	1			450	1	450	1	525	1
p14274	750	1								
p14275	600	1	825	1	1050	1	1050	1	1200	1
p14276	750	1	900	1	1050	1	1200	1	1350	1
p14277	1200	1			1350	1	1500	1	1500	1
p14278	1200	1			1500	1	1650	1	1650	1
p14279	1200	1	1350	1	1650	1	1800	1	1800	1
p14280	600	1			750	1	825	1	900	1
p14281	600	1			750	1	825	1	900	1
p14282	600	1			750	1	825	1	900	1
p14283	525	1	600	1	750	1	825	1	1050	1
p14284	675	1			900	1	1050	1	1200	1
p14285	750	1	825	1	1050	1	1050	1	1350	1
p14286	525	1							600	1
p14287	600	1			675	1	675	1	825	1
p14288	525	1			750	1	825	1	900	1
p14289	900	1	1200	1	1350	1	1500	1	1800	1
p14290	1.2W x 0.9H	1	1200	1	1500	1	1650	1	1950	1
p14291	600	1			900	1	1050	1	1200	1
p14292	675	1	750	1	1200	1	1350	1	1500	1
p14293	750	1			1200	1	1350	1	1500	1
p14294	1050	1			1200	1	1350	1	1500	1
p14295	600	1			675	1	750	1	900	1
p14296	750	1							900	1
p14297	525	1			675	1	750	1	900	1
p14298	675	1	900	1	1200	1	1350	1	1650	1
p14299	525	1	750	1	1050	1	1200	1	1350	1
p14300	525	1			600	1	675	1	750	1
p14301	525	1	750	1	1050	1	1050	1	1350	1
p14302	525	1								
p14303	525	1					600	1	675	1
p14304	525	1	600	1	825	1	900	1	1050	1
p14305	750	1			1200	1	1350	1	1500	1
p14306	900	1			1200	1	1350	1	1500	1
p14307	900	1	1200	1	1650	1	1800	1	2100	1
p14308	1500	1			1650	1	1800	1	2100	1
p14309	1800	1			1950	1	2250	1	2550	1
p14310	525	1					600	1	675	1
p14311	900	1			1350	1	1500	1	1800	1
p14312	1200	1			1500	1	1650	1	1950	1
p14313	375	1	600	1	675	1	600	1	675	1
p14314	375	1	600	1	750	1	675	1	750	1
p14315	375	1					450	1	450	1
p14316	375	1								
p14317	525	1							600	1
p14318	525	1					600	1	675	1
p14319	375	1			525	1	525	1	600	1
p14320	375	1	675	1	1050	1	1050	1	1200	1
p14321	375	1								
p14322										

Pipe	Existing	number	Upgraded Diameter							
Name	Dia.	of pipes	2y	no.	10y	no.	20y	no.	100y	no.
p10532	300	1	675	1	825	1	1050	1	1050	1
p11004	375	1	450	1	525	1	600	1	600	1
p11006	375	1	450	1	525	1	600	1	600	1
p11010	300	1	600	1	600	1	675	1	675	1
p11012	375	1	600	1	675	1	750	1	825	1
p11014	375	1	600	1	675	1	750	1	825	1
p11016	375	1	600	1	675	1	750	1	825	1
p11020	375	1	600	1	675	1	750	1	825	1
p11008	300	1	375	1	450	1	450	1	525	1
p11018	375	1								
p11024	300	1	375	1	450	1	450	1	575	1
p11028	375	1								
p11030	375	1								
p11034	375	1							450	1
p11040	375	1			450	1	450	1	450	1
p11042	375	1			450	1	525	1	525	1
p11072	750	1	900	1	1050	1	1050	1	1200	1
p11032	375	1								
p11036	375	1								
p11038	375	1								
p11044	300	1	450	1	525	1	600	1	600	1
p11046	375	1	600	1	600	1	750	1	750	1
p11048	450	1	600	1	750	1	825	1	825	1

Appendix F

APPENDIX F: FLOOD LEVELS UPSTREAM OF CENTENARY DRIVE

F1. GENERAL

The study area was extended to include Strathfield Golf Course upstream of Centenary Drive. This was undertaken by establishing a hydrologic model (WBNM) to determine the inflows and a hydraulic model (TUFLOW) to determine design flood levels, velocities and extents based on the WBNM inflows.

F2. HYDROLOGIC MODEL

The Watershed Bounded Network Model (WBNM) is a runoff-routing model which provides for both areal and temporal distribution of rainfall as well as non-linear flood routing. It has been modified to simulate the effects of catchment urbanisation. WBNM was adopted as it was the hydrologic model used in the 2009 Sydney Water Flood Study (Reference 1 of main report) and thus the results can be verified against those in this reference. The WBNM model layout is shown on Figure F1 with the adopted model parameters the same as used for Reference 1.

C (storage routing) = 1.6
Initial Loss (pervious) = 10 mm
Continuing Loss (pervious) = 2.5 mm/h

In order to account for the effects of urbanisation the loss rates were decreased, an impervious lag parameter of 0.1 was adopted and a stream lag (shortening) parameter of 0.33 adopted. These were the same as used in Reference 1. Table F1 provides a comparison between the present results and those provided in Reference 1.

Table F1: Comparison of Peak Flows at Centenary Drive (m^3/s)

	WBNM	Reference 1	Difference
2y 120m	70	66	+7%
20y 120m	138	138	0%
100y 120m	182	181	0%
PMF	584	449	+30%

F3. HYDRAULIC MODEL

The hydraulics of the study area was modelled using TUFLOW (2m by 2m grid size) with the topography based on the ALS provided by Council. Table F2 provides a comparison of peak water levels at key locations for the range of design events.

Table F2: Peak Water Levels (m AHD)

Location	2 year	5 year	10 year	20 year	100 year	200 year	PMF
Upstream model limit	22.8	22.9	23.0	23.2	23.3	23.4	25.5
Midpoint of creek	21.2	21.5	21.7	22	22.5	22.7	25.5
Upstream of rail bridge	20.9	21.4	21.7	22	22.4	22.6	25.5

Depth and flood level contours for the design events are shown on Figures F2 to F8 and flood hazard categorisation provided on Figures F9 to F15.

J:\Jobs\29034\Arcview\Arcmaps\FigureF1_wbnmmodelsubcatchments.mxd

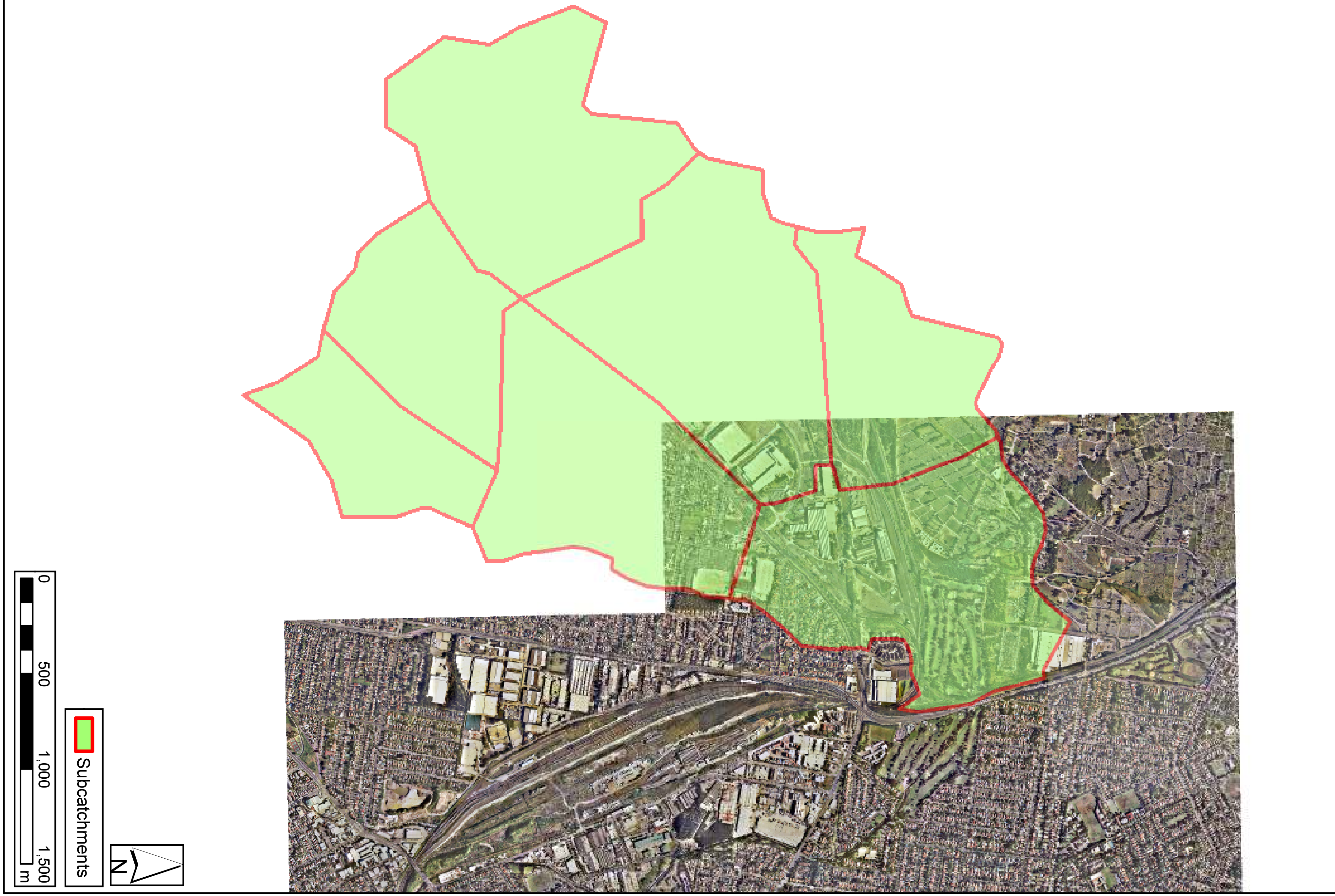


FIGURE F1

WBNM MODEL SUBCATCHMENTS

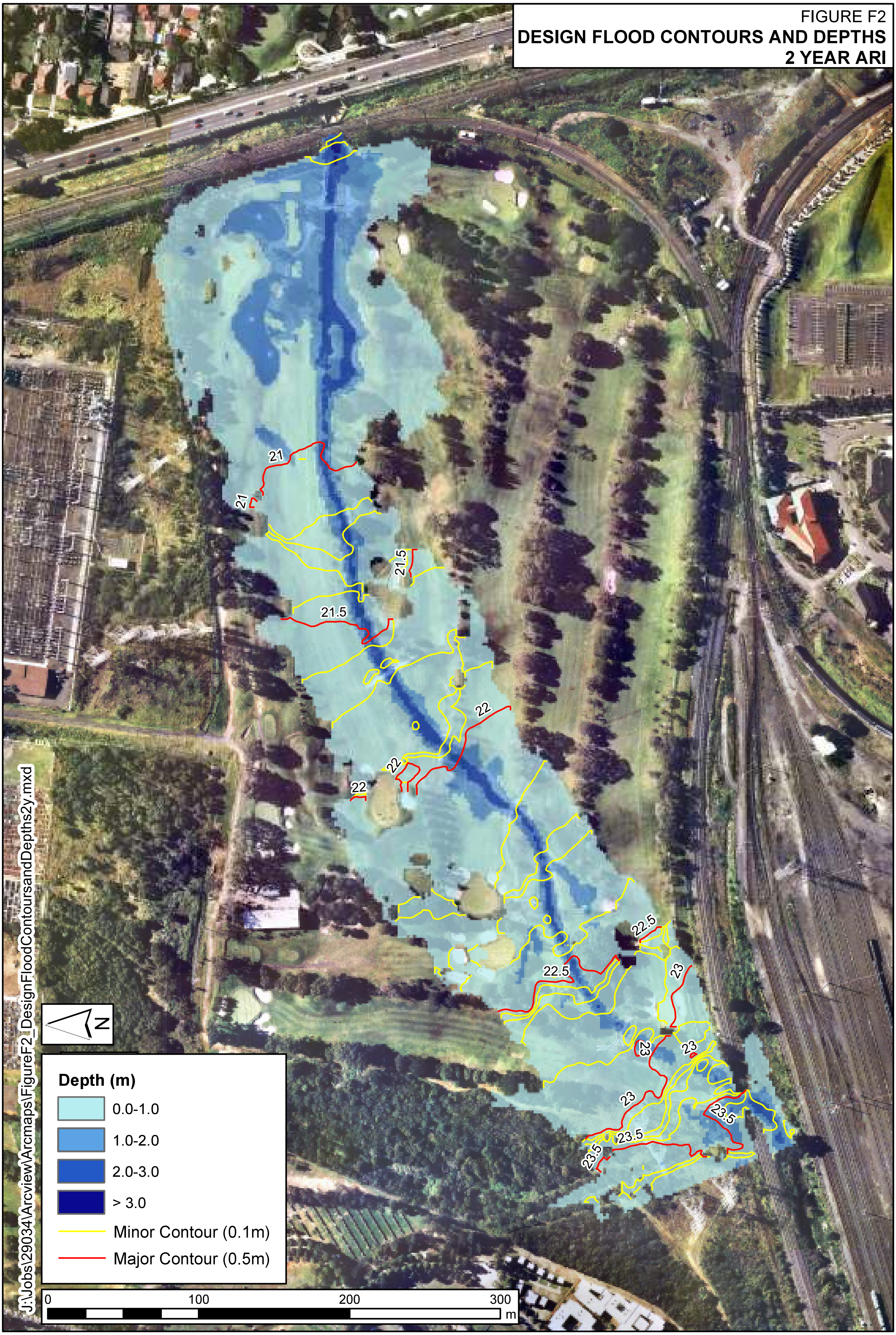


FIGURE F2
DESIGN FLOOD CONTOURS AND DEPTHS
2 YEAR ARI
21
21
21.5
21.5
22
22
22
22.5
22.5
23
23
23
23
23.5
23.5
23.5
N
Depth (m)
0.0-1.0
1.0-2.0
2.0-3.0
> 3.0
Minor Contour (0.1m)
Major Contour (0.5m)
0
100
200
300
m
J:\Jobs\29034\Arcview\Arcmaps\FigureF2_DesignFloodContoursandDepths2y.mxd

FIGURE F3

DESIGN FLOOD CONTOURS AND DEPTHS
5 YEAR ARI

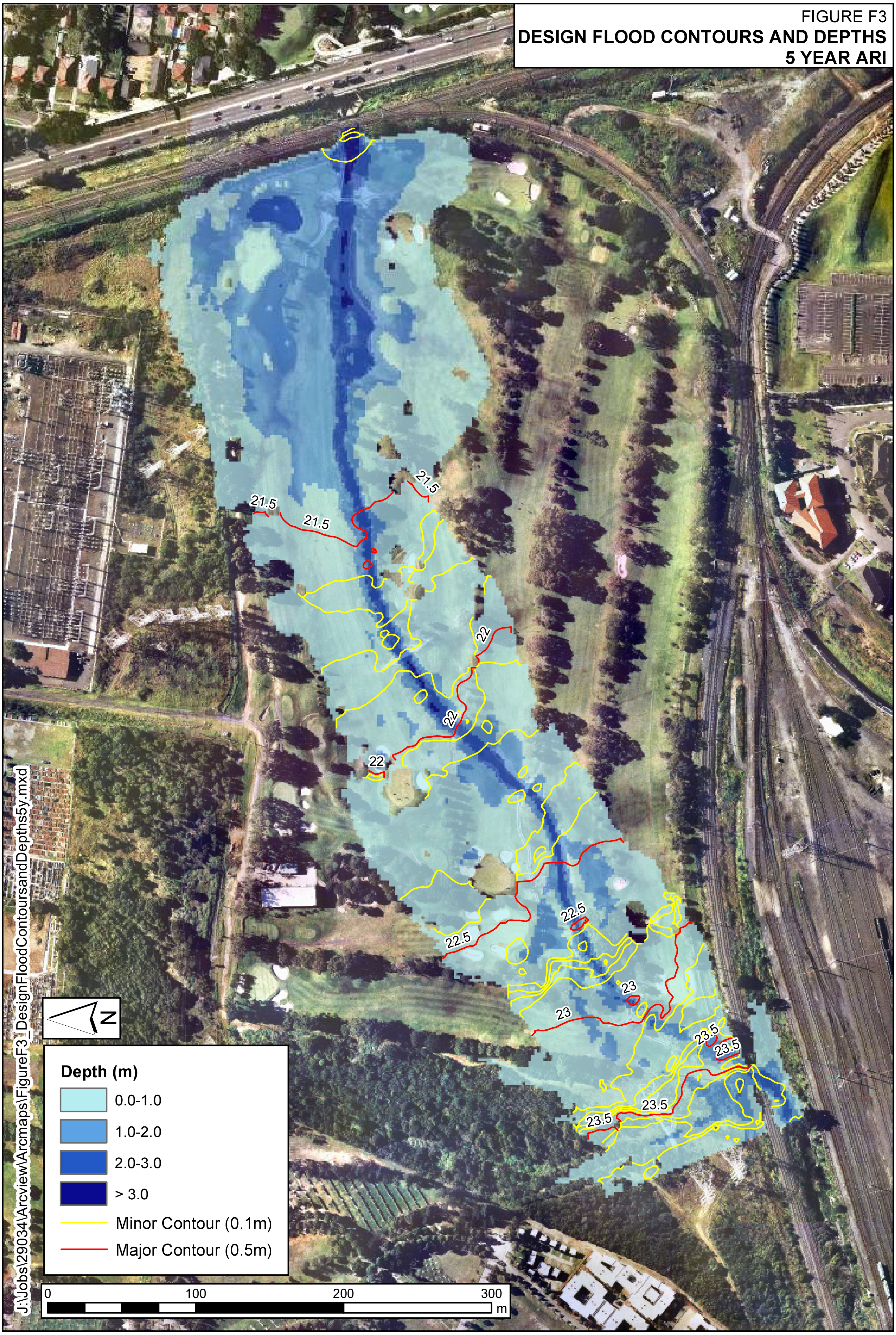


FIGURE F4
DESIGN FLOOD CONTOURS AND DEPTHS 10 YEAR ARI

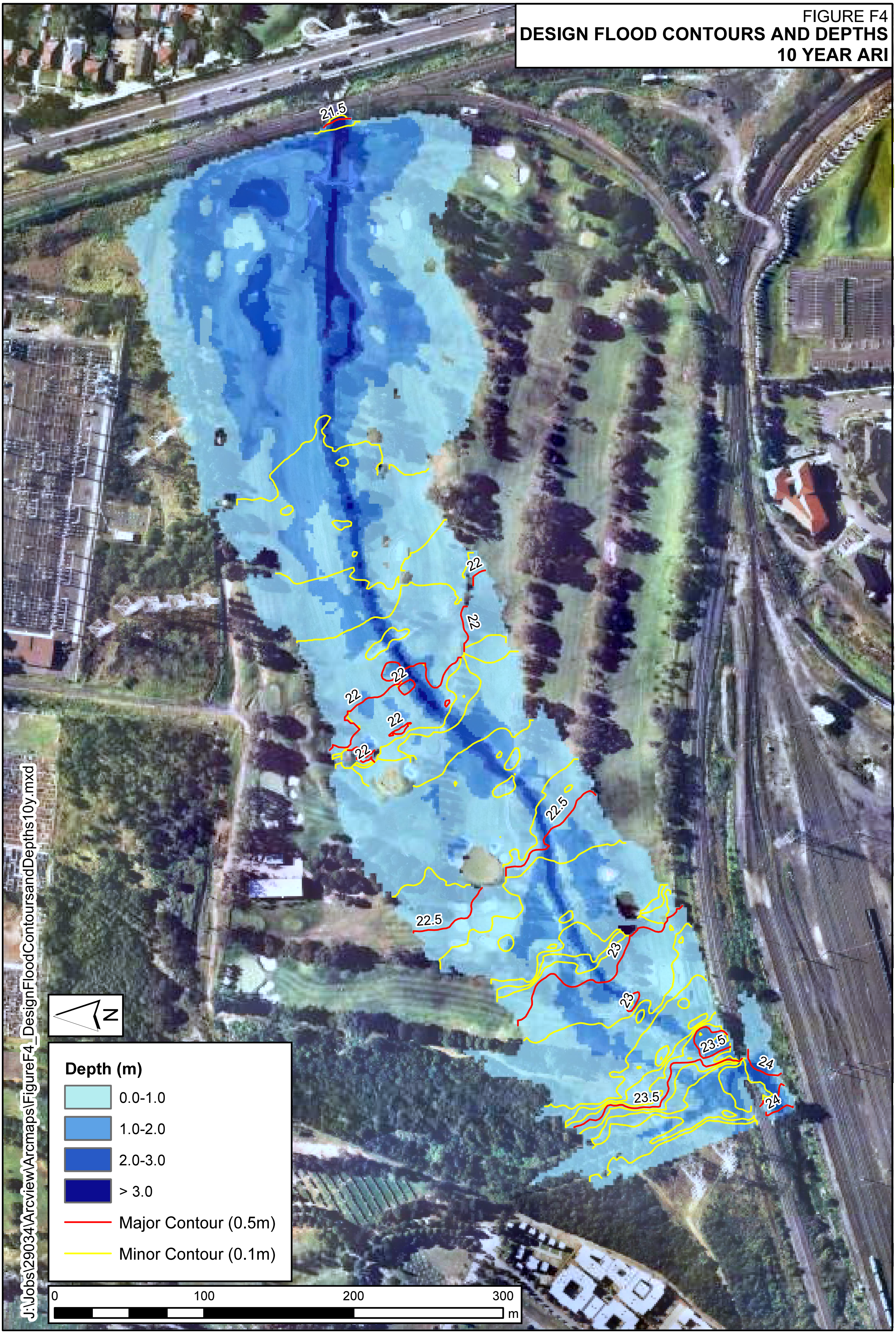


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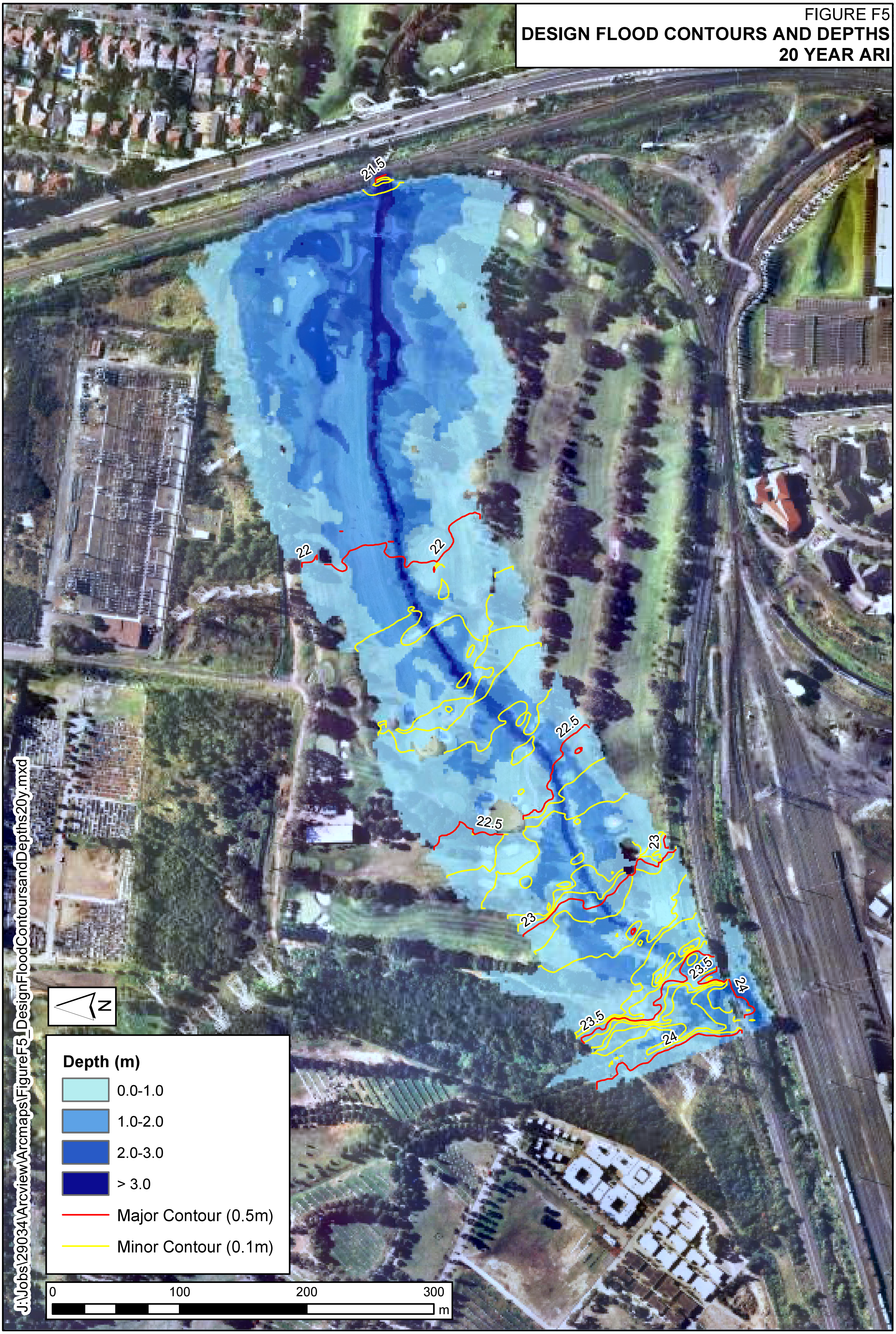
FIGURE F5
DESIGN FLOOD CONTOURS AND DEPTHS
20 YEAR ARI



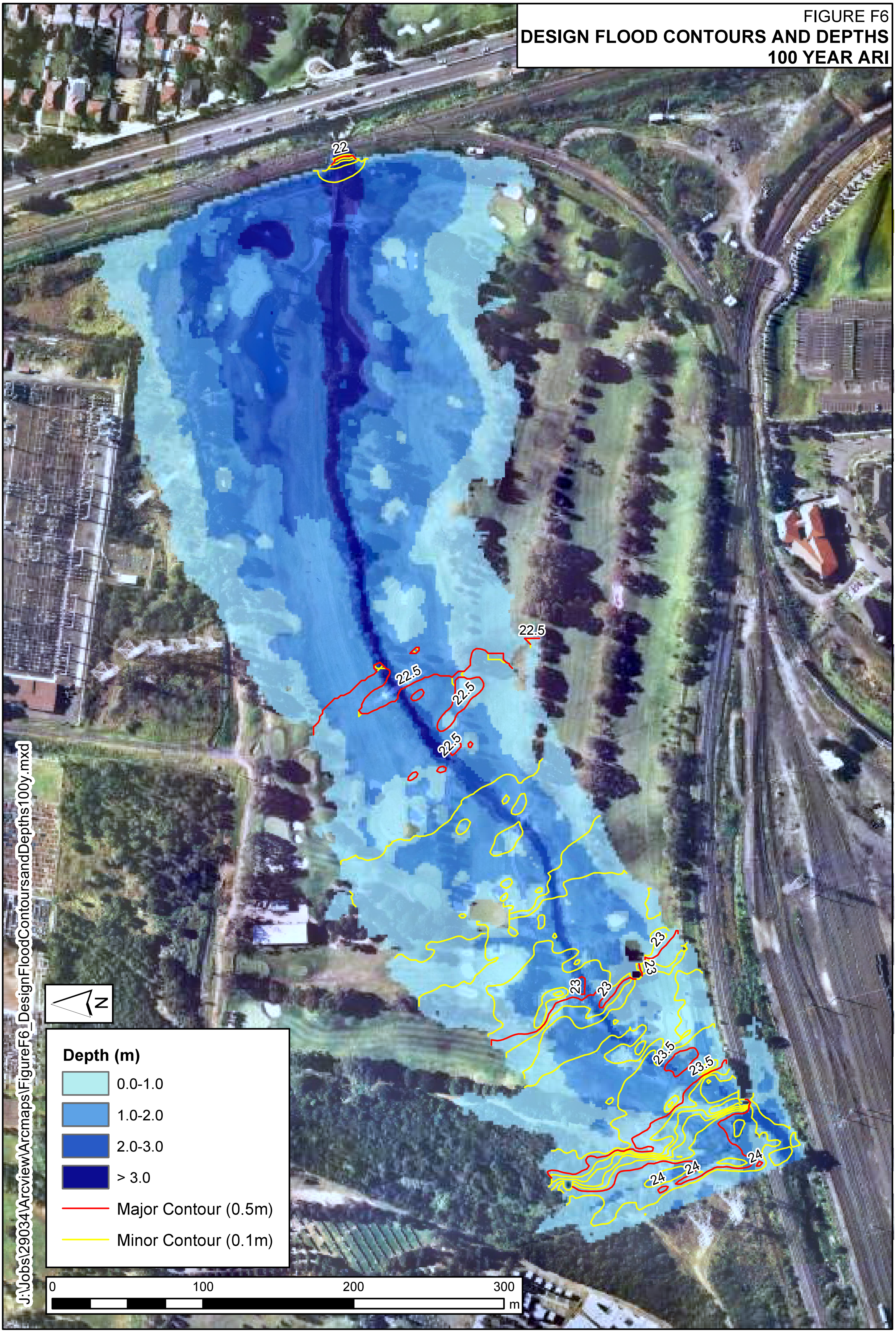


FIGURE F6
DESIGN FLOOD CONTOURS AND DEPTHS
100 YEAR ARI
22
22.5
22.5
22.5
22.5
23
23
23
23
23.5
23.5
24
24
24
N
Depth (m)
0.0-1.0
1.0-2.0
2.0-3.0
> 3.0
Major Contour (0.5m)
Minor Contour (0.1m)
0
100
200
300
m
J:\Jobs\290034\Arcview\Arcmaps\FigureF6_DesignFloodContoursandDepths100y.mxd

FIGURE F7
DESIGN FLOOD CONTOURS AND DEPTHS
200 YEAR ARI

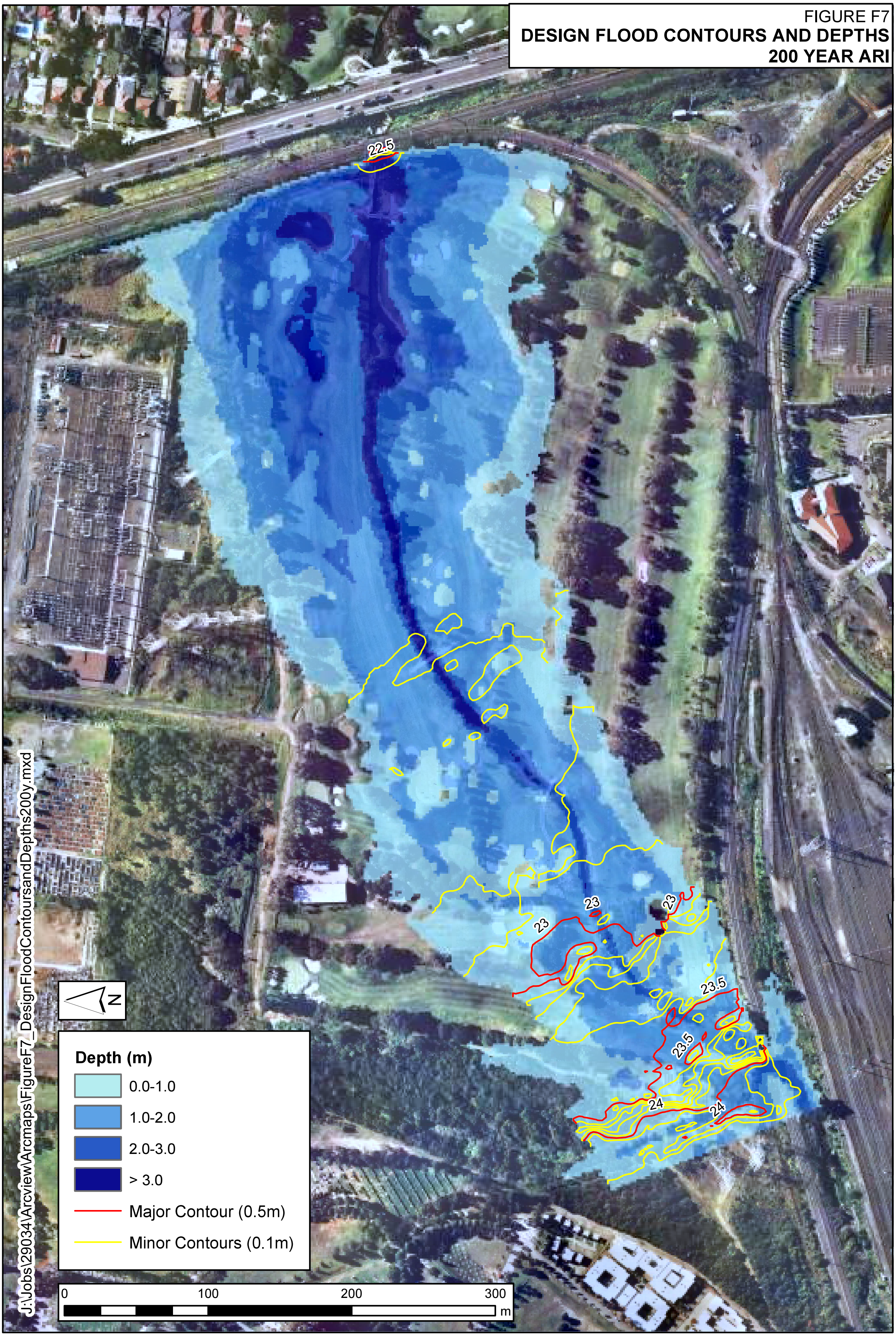


FIGURE F8
DESIGN FLOOD CONTOURS AND DEPTHS
PMF EVENT

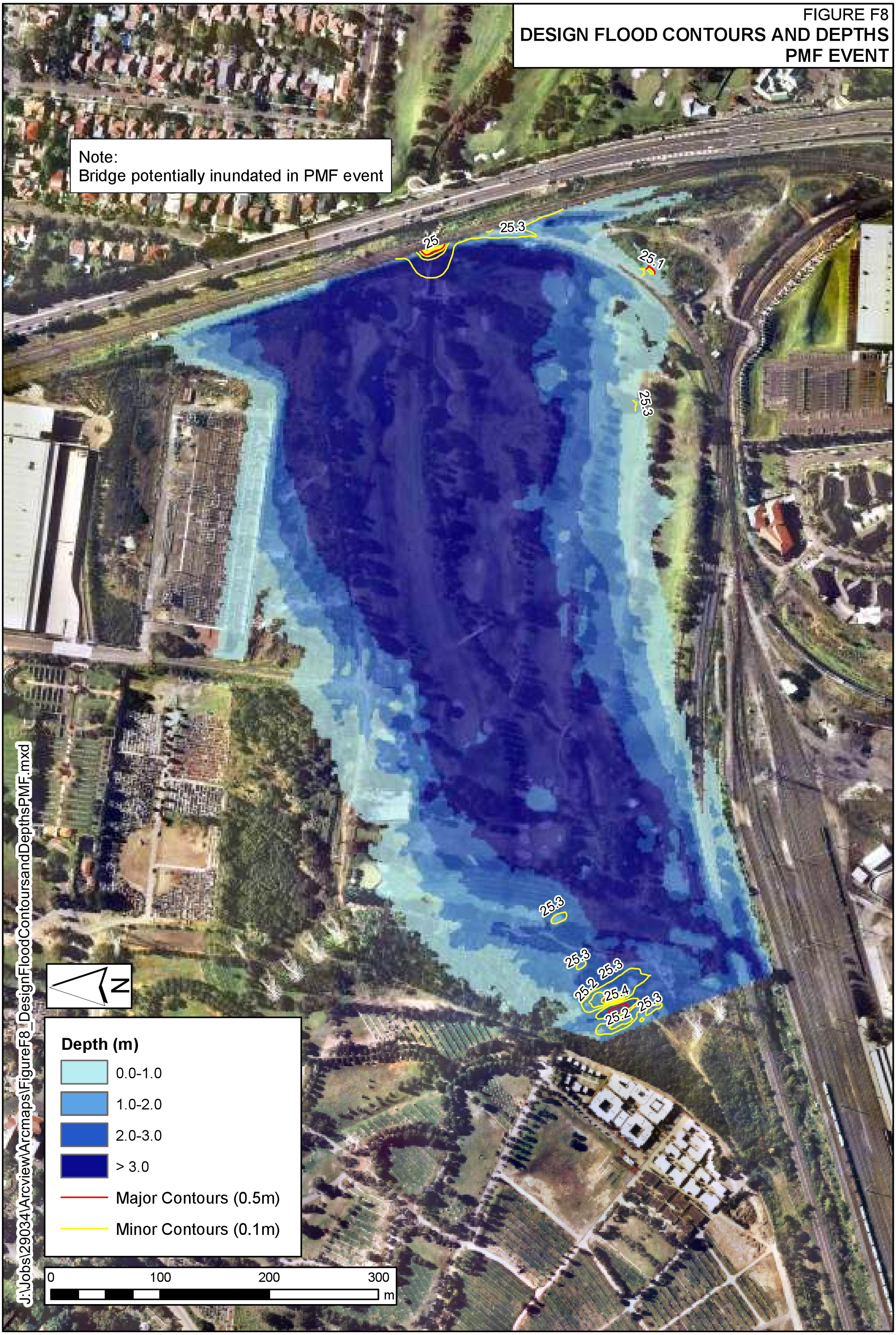
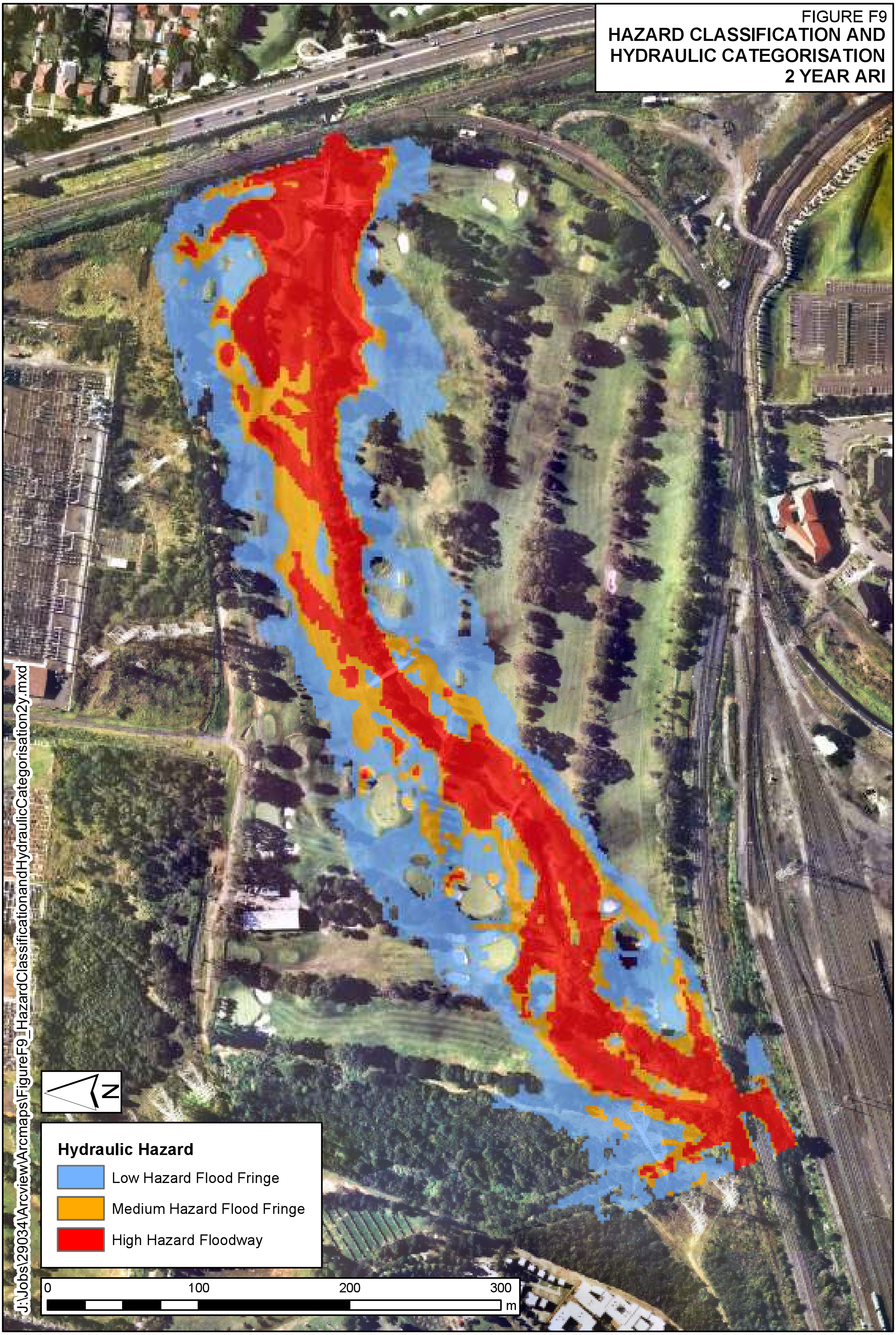


FIGURE F9
HAZARD CLASSIFICATION AND HYDRAULIC CATEGORISATION 2 YEAR ARI



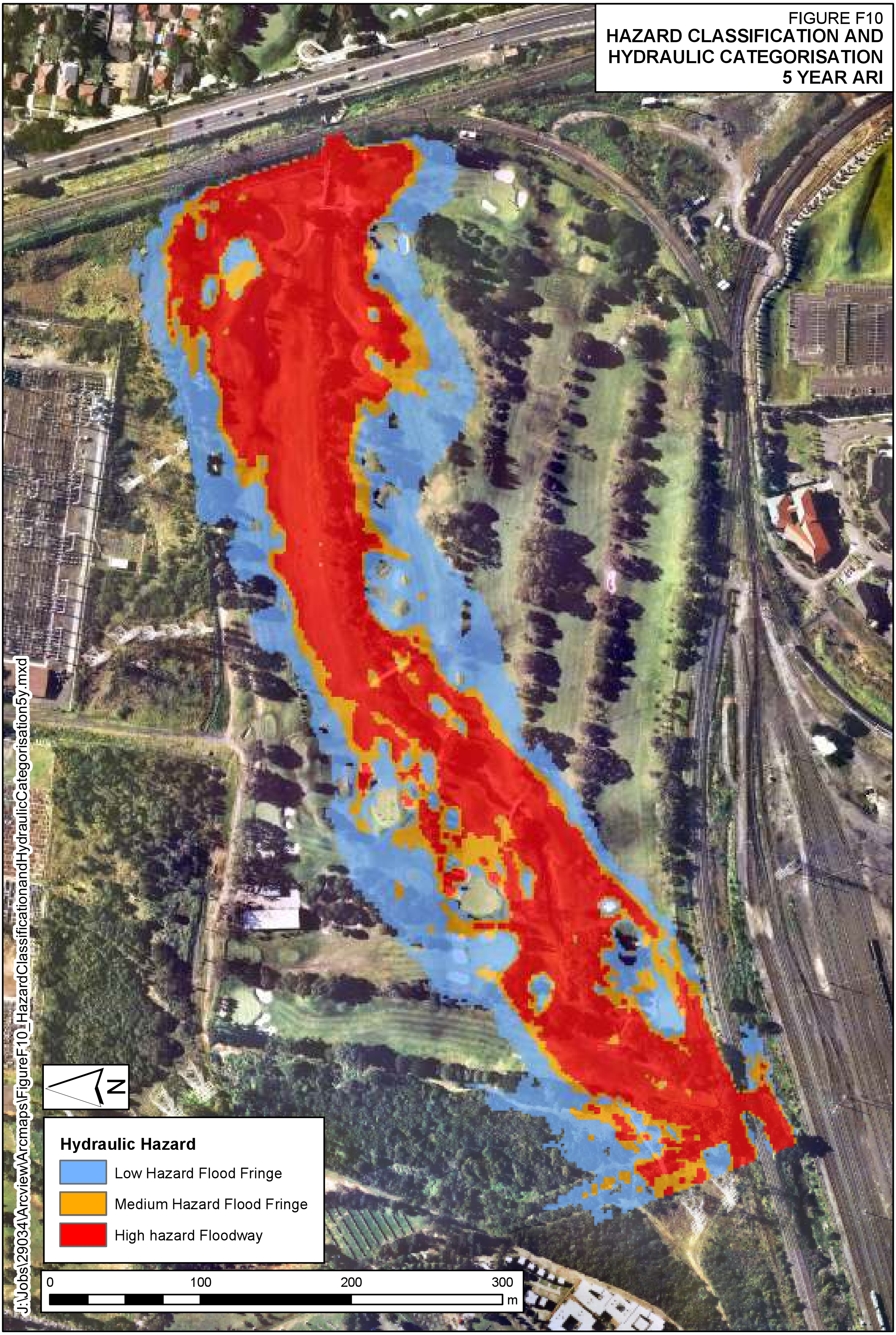


FIGURE F10
HAZARD CLASSIFICATION AND HYDRAULIC CATEGORISATION 5 YEAR ARI

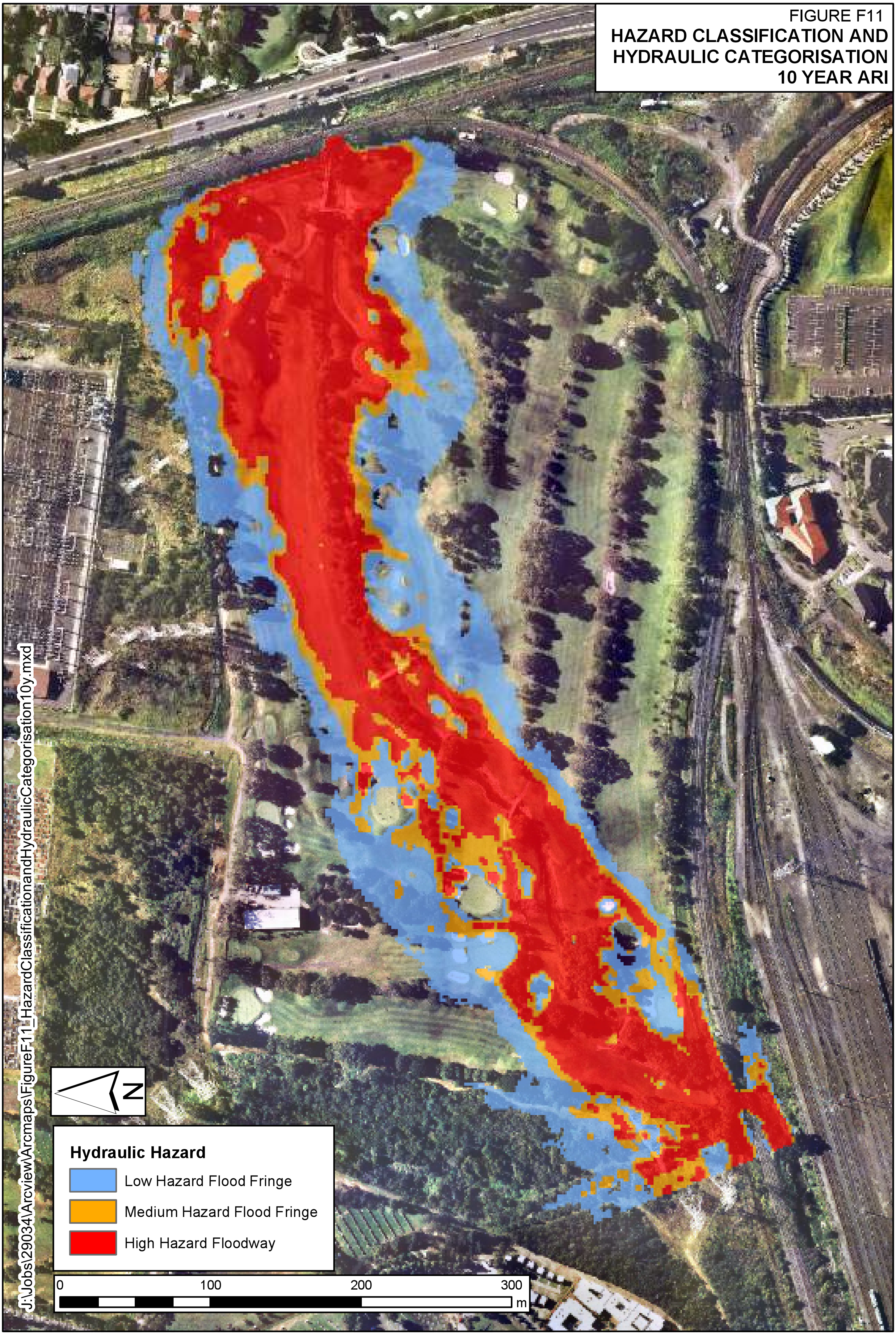


FIGURE F11
HAZARD CLASSIFICATION AND HYDRAULIC CATEGORISATION 10 YEAR ARI

FIGURE F12
HAZARD CLASSIFICATION AND HYDRAULIC CATEGORISATION 20 YEAR ARI

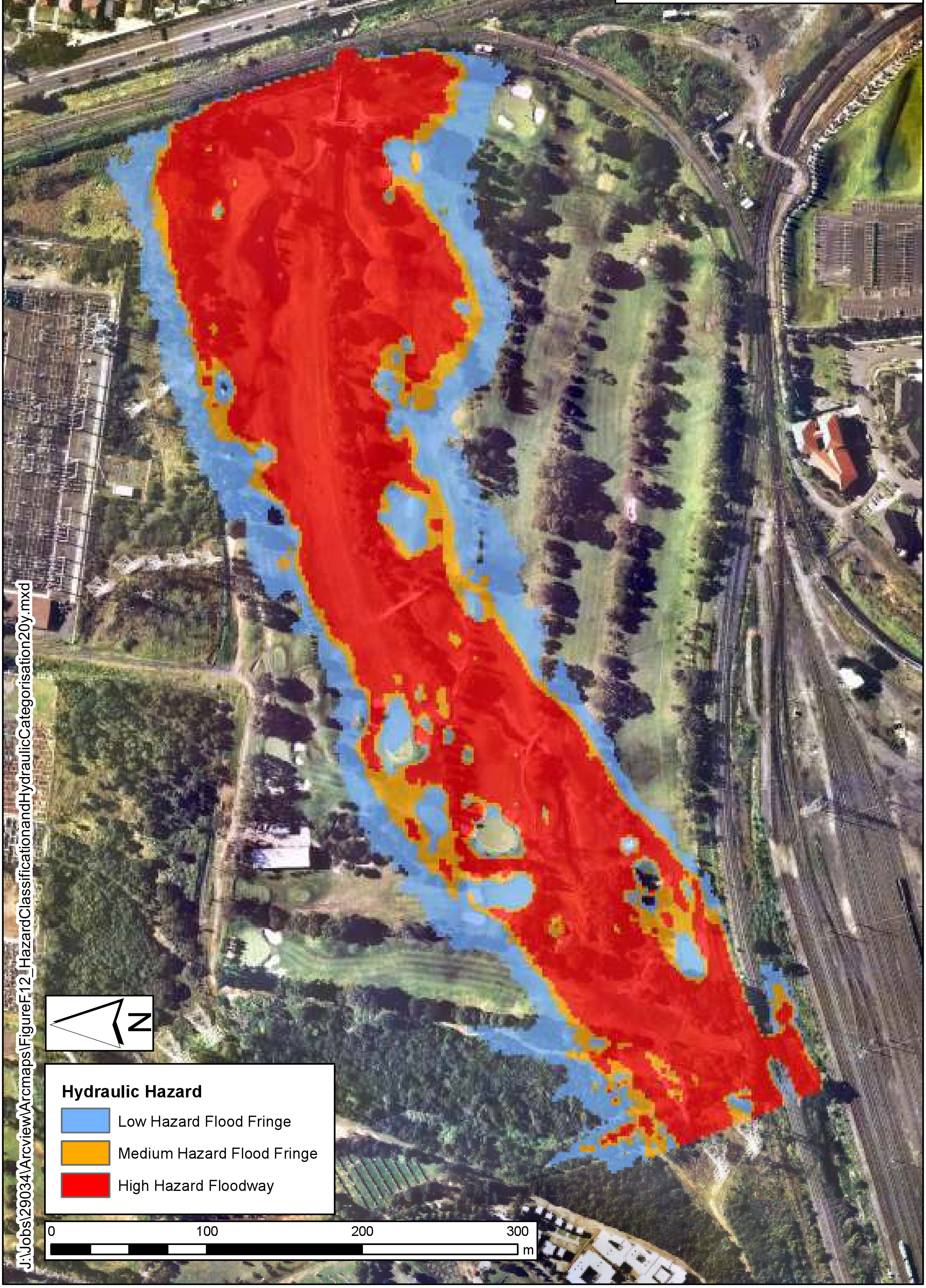


FIGURE F13
HAZARD CLASSIFICATION AND HYDRAULIC CATEGORISATION 100 YEAR ARI

FIGURE F14
HAZARD CLASSIFICATION AND HYDRAULIC CATEGORISATION 200 YEAR ARI


FIGURE F15
HAZARD CLASSIFICATION AND
HYDRAULIC CATERGORISATION
PMF
N
Hydraulic Hazard
Low Hazard Flood Fringe
Medium Hazard Flood Fringe
High Hazard Floodway
0
100
200
300
m
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