DRAFT FOR PUBLIC EXHIBITION

Appendix D

13 October 2016

WRL Ref: L20161013_WRL2016029_gps

Mr Stephen Gray
Director
WMAwater
Level 2
160 Clarence St
Sydney NSW 2000

By email: gray@wmawater.com.au

Dear Stephen,

RE: Peer Review of Dobroyd and Hawthorne Canal Flood Studies: Summation

Thank you for your response (your ref: 116043/L160926) to my letter dated 25 May 2016 (our ref: L20160525) in which I sought additional information and clarifications to the WMAwater flood study reports for Dobroyd and Hawthorne Canals. Your response has generally answered my concerns with original reporting of these flood studies. I have appended both these documents to this letter for ease of reference.

Your response provided additional information regarding the flood study data analysis and numerical modelling for the sixteen (16) specific queries that I had raised. I understand that, predominantly, you had the information for your response at-hand, but had not fully documented it in the study reports. I am of the strong opinion that this additional information is important for Council's and the community's understanding of the methods used and assumptions made in the flood studies. I recommend that this additional information and analysis be included in the floodplain management study report as it provides important baseline information for floodplain management decision makers.

I understand that the amalgamation of the former Ashfield, Leichardt and Marrickville Councils to form the Inner West Council has provided the opportunity for the Hawthorne Canal Flood Study to be expanded to include the former Leichardt Council area and the model recalibrated. This will provide an excellent opportunity for WMAwater to update the study with information similar to that provided in your letter of 25 May, 2016.

Based on the combined information from the flood studies, supplemented by the information from your letter, I am of the opinion that the methodology WMAwater applied to audit and review the data available to the studies is sound. Using this available data, the approach applied to configure and interface the hydrologic and hydraulic models is also sound.

The quality of the hydrologic and hydraulic model outputs is highly dependent on the quality of the input datasets. While the topographic data including survey of hydraulic structures used to configure the models is of a generally high quality, the model 'calibration' datasets for historical floods are of lower quality. While indicative of locations that have been flooded in the past, the recorded flood levels are of little use to confirm actual peak flood levels during the events. The ARI of the two historical events available for model calibration/validation are no greater than 10 years ARI. This means that a significant extrapolation of the modelled flood behaviour is required to generate flood planning levels at the 100 year ARI. While the models as configured are suitable for predicting 100 year ARI flood behaviour, careful quantification of the uncertainty bounds on the model results by suitable model sensitivity analysis is recommended so that planning decisions can adequately take this into account.

The modelled design flood behaviour is also characterised by floodwaters ponding behind elevated road and railway embankments (my query xv). While the methods used to configure these hydraulic structures in the model (as described) are generally sound, the predicted flood levels behind these structures are likely to be very sensitive to the adopted model head loss coefficients. Unfortunately, the historical flood events do not provide the opportunity to adequately calibrate the headlosses for design flood planning levels. This being the case, I recommend that the uncertainties associated with the headlosses be similarly quantified by sensitivity analysis.

Yours sincerely,

Grantley Smith
Manager

Attachments:
L20165625_2016029gps_signed.pdf
L161007_ReviewResponse_compressed.pdf

25 May 2016

WRL Ref: L20160525_WRL2016029_gps

Mr Stephen Gray
Director
WMAwater
Level 2, 160 Clarence St
Sydney, NSW, 2000

By email: gray@wmawater.com.au

Water Research Laboratory

Dear Stephen,

RE: Peer Review of Dobroyd and Hawthorne Canal Flood Studies

I have completed a first pass review of the WMAwater report "Hawthorne Canal Flood Study" dated 28 October, 2014 and noted as Revision 5.

I have a series of questions and clarifications on the report content that are listed below. I'd request that you provide a response to each of these items below, so that I can progress my peer review of the report. I have similar issues with the Dobroyd Canal Flood Study. Since the studies use the same methodology and modelling approach, many of the answers provided below will likely be the same for both studies. Please indicate in your response if this is the case. However, I expect that queries xiii), xiv), xv) and xvi) as a minimum will require a separate response for each study.

i. Data checking. Please describe how the following datasets were audited/checked for suitability (accuracy) of use in the model. If the model datasets were updated/modified from their raw form, please describe the process for modifying the data.
   a) ALS/Lidar for model DEM;
   b) Pit and pipe data;
   c) Rainfall;

ii. Overall model approach / model development. While I understand the broad modelling approach of combining a DRAINS model of the upper catchment, primarily for generating catchment runoff, and a TUFLOW model to represent the floodplain flow paths, it's not clear to me from the report how the two models interface and which catchment/floodplain elements are included in each model. Please clearly describe how the models interface i.e. which catchment/floodplain components are in the DRAINS model and which are in the TUFLOW model, and how they connect to each other in the model. Please specifically describe how the components of the pit and pipe stormwater system interface with the catchment runoff hydrographs and surface water flow paths. A conceptual model diagram(s) might assist in this regard;

iii. Please describe how the upstream limits of the piped stormwater system in the model were decided.

iv. Please describe the method used to ensure all the potential overland flow paths have been identified for design events greater than the flood of record / most recent flood in the community's 'living memory'?

v. Please demonstrate how it was determined that the model simulations had converged to a 'stable' solution e.g. mass balance checks etc.

vi. **Section 2.5 Pit and Pipe Data** notes "*Lack of this data* (i.e. missing pit and pipe data) *will only impact results to a very small degree and impacts will be less significant for larger events such as the 100 year ARI*". This based on what assessment? Please justify by quantitative analysis e.g. comparison of serviced catchment inflow volume vs. flow capacity of piped system vs. overland flow volume;

vii. **Section 2.6.2 Community Consultation** provides a series of photographs of local flooding and reports of property/floor inundation. The model validation would benefit from a qualitative comparison these data with inundation mapping. Please provide local area mapping comparing photo location / property inundation reports with modelled inundation area for the respective historical flood event;

viii. **Section 2.7 Historic Rainfall Data.** Further information on the spatial variability of rainfall would assist in the interpretation of the model calibration outcomes. Suggest that a graphical representation of rainfall e.g. rainfall isohyets for historical events in the local area, and perhaps also in the wider Sydney area compared to design rainfalls would help put the model calibration in better context;

ix. **Section 2.8 Design Rainfall Data** – were catchment reduction factors applied? If not, why not?

x. **Section 4 Hydrologic Model, 4.1 Sub catchment definition.** There are many sub-catchments. How was the catchment boundary and outlet location of each sub-catchment defined? E.g. area contributing to a stormwater pit?

xi. **Section 5 Hydraulic Model, 5.1 Digital Elevation Model.** The DEM resolution for the Tuflow model was defined as a 3mx3m grid. This is at the upper limit of what I would consider suitable for defining overland flow paths in an urban environment. My knowledge of the catchment is that there are some locations where important overland flow paths, particularly between buildings, would be less than 3m wide. How were these included in the model? Please provide an example.

xii. **Section 6.3.3 Model Calibration**. The model calibration levels are consistently low. Commentary in this section implies this is because there was significant blockage of the stormwater system in the catchment. In my view there are numerous other reasons why the model calibration levels might be consistently low. I think you have two options, either you decide that there are numerous reasons why the calibration is low and test each of these reasons in the model sensitivity testing, or re-calibrate the model with blockage included to demonstrate that levels can be successfully matched and include blockage in the design runs.

xiii. **Section 7.2 Critical Duration** Please provide more information on the critical duration assessment e.g. map showing areas dominated by each duration and/or longitudinal profile showing adopted envelope approach;

xiv. **Section 7.3. Downstream Boundary Conditions** Please provide an explanation of why 1.38 m AHD and 1 m AHD were adopted as design boundary conditions for the Hawthorne Canal Study. Similarly Please explain the logic for selecting the various design boundary conditions outlines in Table 23 of the Dobroyd Canal Flood Study which differ from the Hawthorne Canal study.

xv. **Section 8 Sensitivity Analysis.** Quantification of the accuracy and uncertainty of the design model outputs is important for floodplain management decision making. In this catchment, where there is little calibration data, sensitivity analysis is the primary source of information for uncertainty. Figures 26a and 26b demonstrate that headloss at hydraulic structures is an important consideration since floodwaters backing up behind these structures are a dominant feature controlling inundation in the catchment. Please demonstrate how the adopted model headloss coefficients were checked. Understanding sensitivity of model outputs to culvert headlosses is important. This has been partially covered off in the blockage analysis. Please demonstrate the model sensitivity to head loss changes.

xvi. Council has noted several locations where either the Council or the local community has concern with the model results. Could you please name these locations, summarise the Council/community concerns, and for each floodplain location provide a detailed description of the model configuration, model calibration/validation results and design model results.

Yours sincerely,

Grantley Smith
Manager

Water Research Laboratory
110 King Street
Manly Vale NSW 2093

116043/L161007_ReviewResponse.docx

7 October 2016

Attention: Mr G Smith

Dear Grantley,

Re: Response to Letter "Peer Review of Dobroyd and Hawthorne Canal Flood Studies" dated 25 May 2016

Please see below for response to questions tendered in the above referenced letter.

Item i)

As part of the Flood Study work, WMAwater commissioned Chase Burke & Harvey (CBH) Surveyors to collect levels and cross-section data in the open channel and at bridges over the open channel. This data was used to create the 1D open channel network within the hydraulic model. Where the 1D domain (using the surveyed levels) intersected with the 2D domain (using the ALS data), such as the bridge deck levels and the top of bank/channel levels, the surveyed levels were compared to the ALS to assess the suitability of the ALS for defining the topography in the 2D domain.

The DEM used in the 2D domain was also updated/modified in the following ways:

- TUFLOW breaklines were used to assign the elevations in the road gutters as 0.15 m below the ALS levels, as the gutter widths are smaller than the ALS resolution and hence outside the capacity of the ALS to precisely represent.
- Bridges over roadways, where the roadway acted as a flowpath (such as the railway bridge over Frederick Street and the railway bridge over Brown Street) had the DEM modified locally as the ALS data could not penetrate the bridges. In these situations the DEM on the roadway underneath the bridge was assigned the elevation of the roadway at locations on either side of the bridge. A 2D bridge structure was then schematised over the roadway in the hydraulic model.

Invert data was determined / estimated using a number of methods:

- Along the open channel, inverts were interpolated from cross-section and hydraulic structure survey locations;
- Along Sydney Water Corporation (SWC) drainage infrastructure, the inverts were estimated using the pipe slopes reported in the SWC Capacity Assessment Reports (SWC, 1998);
- Along Council drainage infrastructure, the inverts were provided by Council; and

- Where invert data was not available, the inverts were estimated from the ALS level and an assumed depth.

The invert data was then checked to ensure that the entire connected drainage infrastructure had a positive grade from downstream to upstream.

The observed rainfall data was sourced from the Bureau of Meteorology (BOM) and Sydney Water Corporation (SWC). Both agencies quality control check and verify the data that they collect, with the BOM publishing details of the Quality Assurance (QA) process undertaken at:
http://www.bom.gov.au/climate/data-services/content/quality-control.html

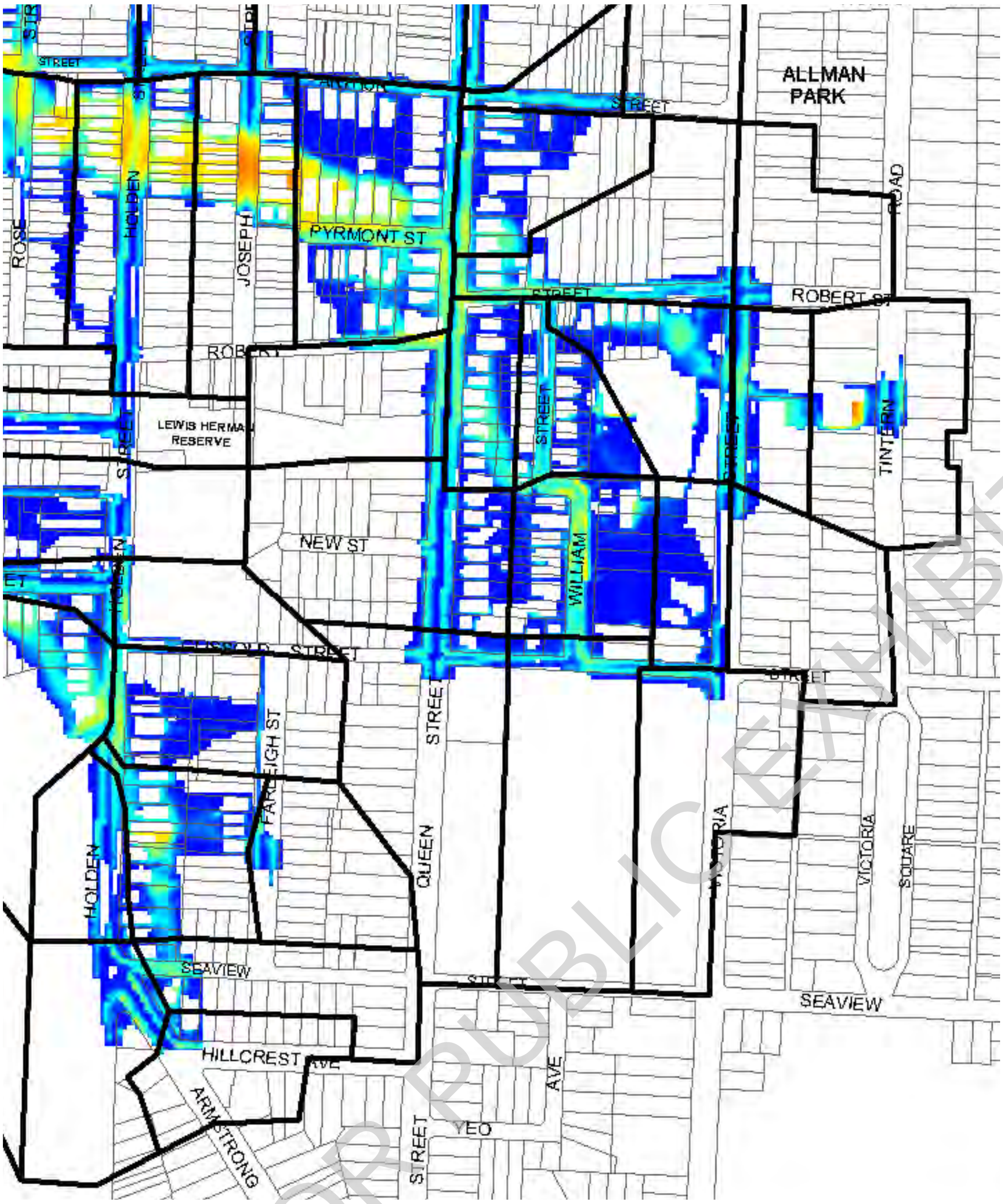
Item ii)
DRAINS was used for the hydrologic model for the conversion of rainfall into flow. The catchment/floodplain elements included in the DRAINS model were: sub-catchment area, sub-catchment slope, impervious percentage, and rainfall losses. No routing of flows between sub-catchments was undertaken in DRAINS (instead this was undertaken in the TUFLOW hydraulic model), and hence no pipe dimensions or overland flow path dimensions were defined in the DRAINS model.

The flows from each individual sub-catchment from the DRAINS model were input into the 2D TUFLOW hydraulic model as point inflows. These point inflows were located at the downstream boundary to each sub-catchment and corresponded to the kerb and gutter system. This emulates the way most properties are designed to drain intralot flow and roof flow into the street gutters.

Within TUFLOW, flow applied to the gutter system (modelled in the 2D domain) travels based on elevation and roughness (Manning's value) and enters the pit and pipe system (modelled in the 1D domain) via 1D-2D connections.

Item iii)
The upstream limits of the piped stormwater system were based upon pipe elements that were equal to or greater than 450 mm in diameter in the Council drainage database.

Item iv)
The highest upstream inflows were located as far upstream as the stormwater drainage network extended. The average sub-catchment size of 0.015 km^2 ensured that where overland flow paths existed, these were represented in the hydraulic model (as shown below).



Item v)

The model simulations were determined to be ‘stable’ based upon assessment of:

- the mass balance outputs (in the order of 0.1% in the 1% AEP event). This assures that globally, the hydraulic model is not generating or losing significant mass;
- the peak velocity outputs, as a high velocity may be indicative of stability issues; and
- the hydrograph outputs generated across the hydraulic model.

Item vi)

The pipes servicing Parramatta Road (where pipe dimensions were unavailable) spanned relatively short lengths (less than 300 m in length) and drained relative small local catchments (in the order of 0.06 km^2). The SWC stormwater pipes that the pipes along Parramatta Road discharged into were found to be operating at capacity in events as small as the 2 year ARI (in which event, the pipes were full for approximately 1.3 hrs over the course of a 1 hr storm duration).

Additionally, the sensitivity of the model to the size of these unknown pipes were assessed for the 1% AEP event by doubling the assumed size of the unknown pipes. This resulted in a peak flood level increase of 0.016 m.

Item vii)
The Hawthorne Canal Flood Study (community consultation phase) received 10 photos of flooding spanning 2009 to 2012. The Flood Study extracted 8 approximate water levels for the 2012 event. The modelled March 2012 peak flood depth compared to the approximate water levels is shown on Figure 17.

Please see Item xii) for further information in this regard.

Item viii)
The spatial distribution of the rainfall depths and IFD ranges is shown on “Item 8A” and “Item 8B” for the February 1993 6 hour storm burst and “Item 8C” and “Item 8D” for the March 2012 6 hour storm burst.

Item ix)
Aerial reduction factors (as per Australian Rainfall and Runoff 1987 (AR&R 1987)) predominantly affect large catchment areas, as shown in Diagram 1 extracted from AR&R 1987. The Dobroyd Canal and Hawthorne Canal catchment areas were less than 10 km^2, and as such the Depth-Area Ratio was converging on 1 (from Diagram 1). Therefore, no catchment reduction factors were applied to the design rainfall data.

Diagram 1: Extract from Australian Rainfall and Runoff (1987)

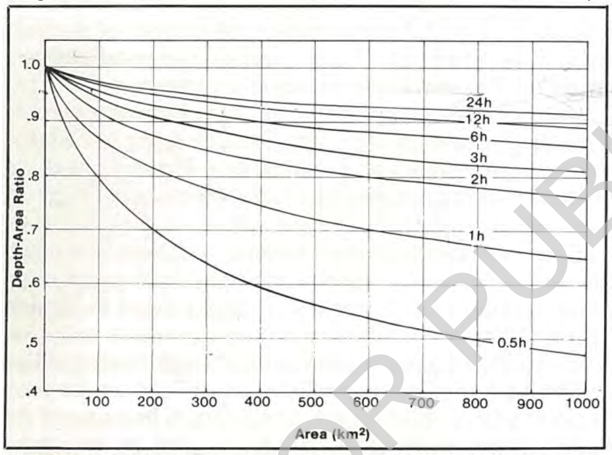
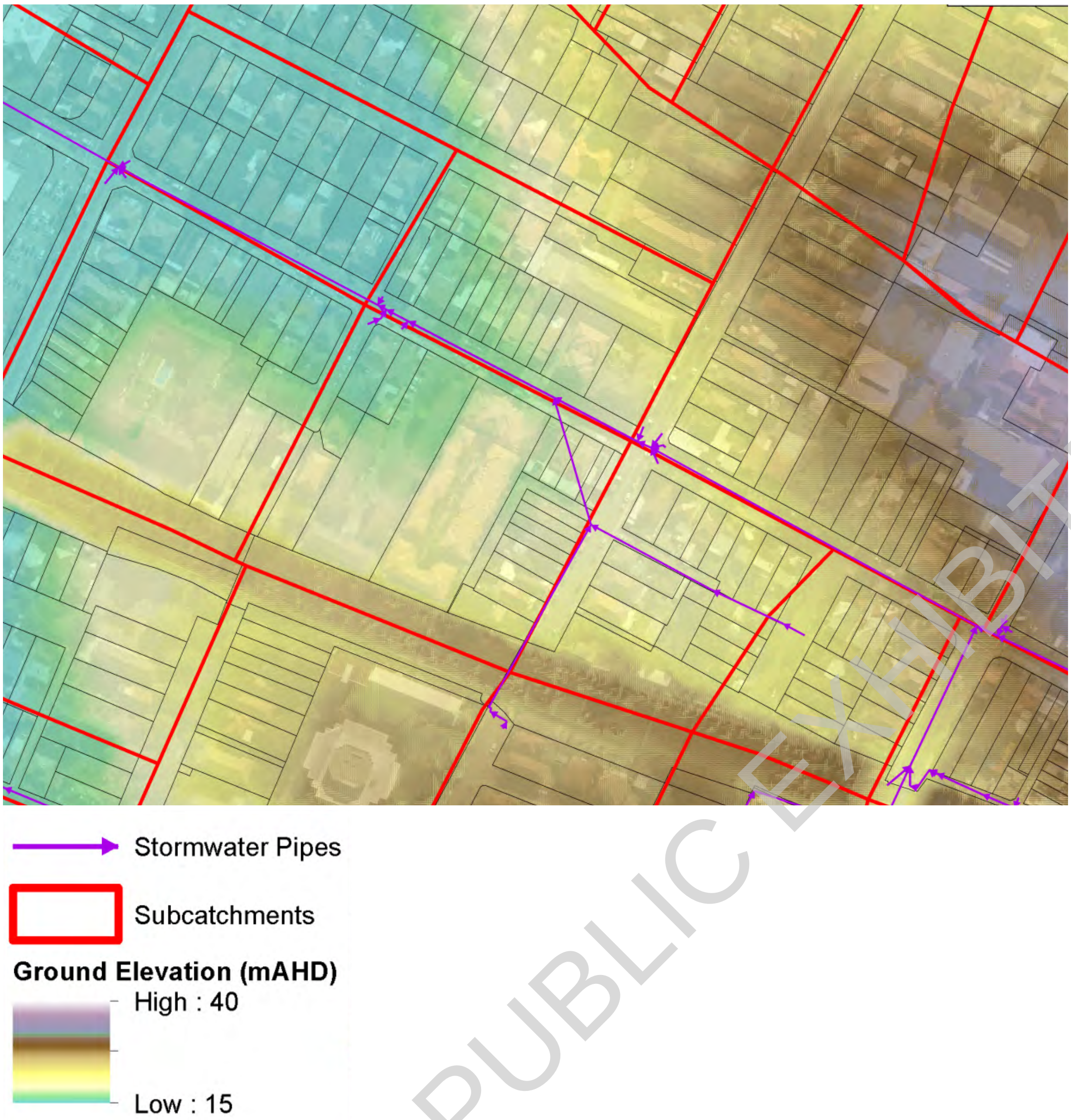


Figure 2.6 - Depth-area ratios for use in Australia (except Zone 5 of Figure 3.2, Chapter 3). (From U.S. NOAA Tech. Report, NWS 24, 1980)

Item x)
Sub-catchments were defined such that each area drained to a stormwater pit. The elevation and major features like roads or crests of hills were used to delineate the boundary for each sub-catchment.



Item xi)

Following initial establishment of the modelling, and during the calibration/validation phase of the work, the model results were subject to review. Locations where flood water was being detained upstream of buildings were identified and assessed. Site visits were undertaken. Where the assessment found the upstream detention of flood water to be artificial, the model schematisation of building extents was altered in order to ensure that where in reality flow could travel downstream, the same could also occur in the hydraulic model.

Item xii)

Given review comments in regard to calibration, WMAwater have examined the flood mark set. It is apparent that the flood observations are suitable for describing areas impacted by flooding but not appropriate for use in exact flood level comparisons. This conclusion is based on the fact that the flood level estimates (which are in turn based on observations of flooding submitted by the community) are clearly approximate in nature. Some in fact, based on review of design flood level estimates, would appear to be difficult to achieve even given the occurrence of a PMF event. As such, WMAwater submit that rather than a level comparison exercise, these points are best used as an indication of which areas are subject to some degree of flooding, for a given event.

In May 2016, the former Ashfield Council, Leichhardt Council and Marrickville Council were amalgamated to form the Inner West Council. As a result of the amalgamation, a variation is pending for WMAwater to expand the current Hawthorne Canal Study area to include former Leichhardt Council area (both hydrologic and hydraulic models) and re-calibrate the model.

Item xiii)

The spatial variation of the critical duration for the 1% AEP event in the Dobroyd Canal catchment is shown in “Item 13A”. As per the report, further analysis of the difference between the 1 hour and 2 hour (durations critical along the major drainage lines) was undertaken and shown in “Item 13B”.

The spatial variation of the critical duration for the 1% AEP event in the Hawthorne Canal catchment is shown in “Item 13C”. The difference between the 25 minute and 1 hour (durations critical along the major drainage lines) was undertaken and shown in “Item 13D”.

Item xiv)

The ocean levels used in the Flood Studies were taken from *Fort Denison Sea Level Rise Vulnerability Study* (Department of Environment and Climate Change NSW, October 2008).

However, subsequent to the completion of the Flood Studies further guidance has been released, namely the *Floodplain Risk Management Guide: Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways* (NSW Government and Office of Environment and Heritage, November 2015). The Floodplain Risk Management Study will adopt the ocean levels specified in this document (shown in Table 1).

Table 1: Combinations of Catchment Flooding and Oceanic Inundation Scenarios

Design AEP for peak flood levels	Catchment Flood Scenario	Ocean Water Level Boundary
50% AEP	50% AEP Rainfall	HHWS Ocean Level 1.25 m AHD
20% AEP	20% AEP Rainfall	HHWS Ocean Level 1.25 m AHD
10% AEP	10% AEP Rainfall	HHWS Ocean Level 1.25 m AHD
5% AEP	5% AEP Rainfall	HHWS Ocean Level 1.25 m AHD
2% AEP	2% AEP Rainfall	5% AEP Ocean Level 1.40 m AHD
1% AEP (Enveloped)	5% AEP Rainfall	1% AEP Ocean Level 1.45 m AHD
	1% AEP Rainfall	5% AEP Ocean Level 1.40 m AHD
PMF	PMF Rainfall	1% AEP Ocean Level 1.45 m AHD

Item xv)

There is sensitivity to culvert headlosses. This relates to the fact that many areas rely significantly on drainage via hydraulic structures. Default losses have been used for these structures as, in the absence of any data/observations to suggest that otherwise, this was considered the best approach to use. As the reviewer suggests, blockage sensitivity runs then become a proxy for varying headloss values, and hence such runs indicate the sensitivity of flood levels to varying head loss values.

Additional work undertaken in the Hawthorne Canal Catchment area investigated the afflux across hydraulic structures in the vicinity of Longport Street, Lewisham. The investigation was undertaken using a HEC-RAS hydraulic model. From the HEC-RAS model the afflux across Longport Street was found to be 2.33 m, which is a close match to the 2.36 m afflux found in the TUFLOW model used in the Flood Study.

Item xvi)

Community concerns were less centred on specific locations and were more centred on the whole model process. The Railway Embankment over Dobroyd Canal and the Parramatta Road Bridge over Hawthorne Canal is representative of the hydraulic model configuration across the catchments. At these locations, the open channel is represented as a 1D element, carved into the 2D domain. This is shown in the attached figures.

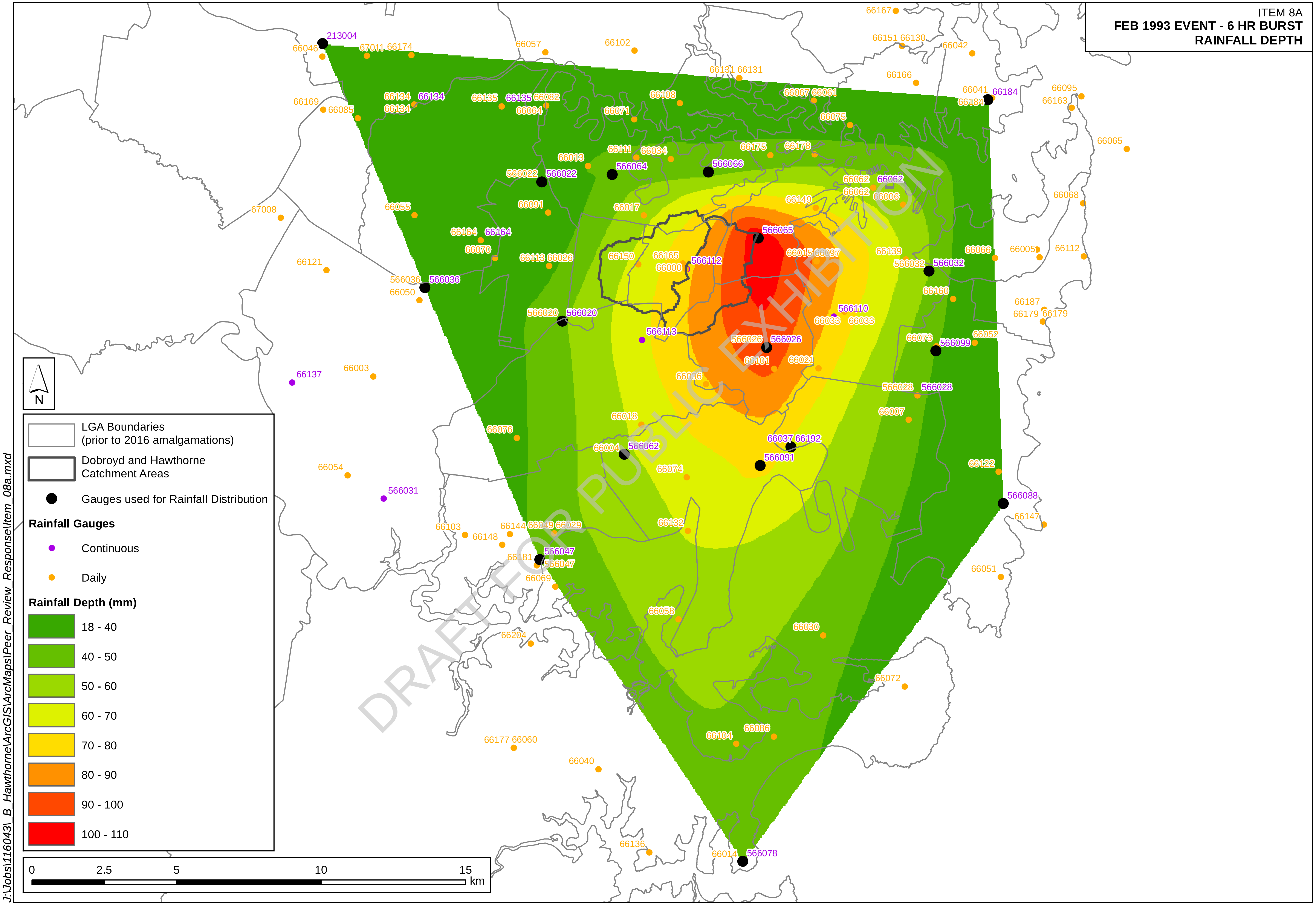
Should you require any further clarification, please do not hesitate to contact the undersigned.

Yours Sincerely,

WMAwater

Stephen Gray

Director


ITEM 8A
FEB 1993 EVENT - 6 HR BURST
RAINFALL DEPTH
N
LGA Boundaries
(prior to 2016 amalgamations)
Dobroyd and Hawthorne
Catchment Areas
Gauges used for Rainfall Distribution
Rainfall Gauges
Continuous
Daily
Rainfall Depth (mm)
18 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
100 - 110
0
2.5
5
10
15
km
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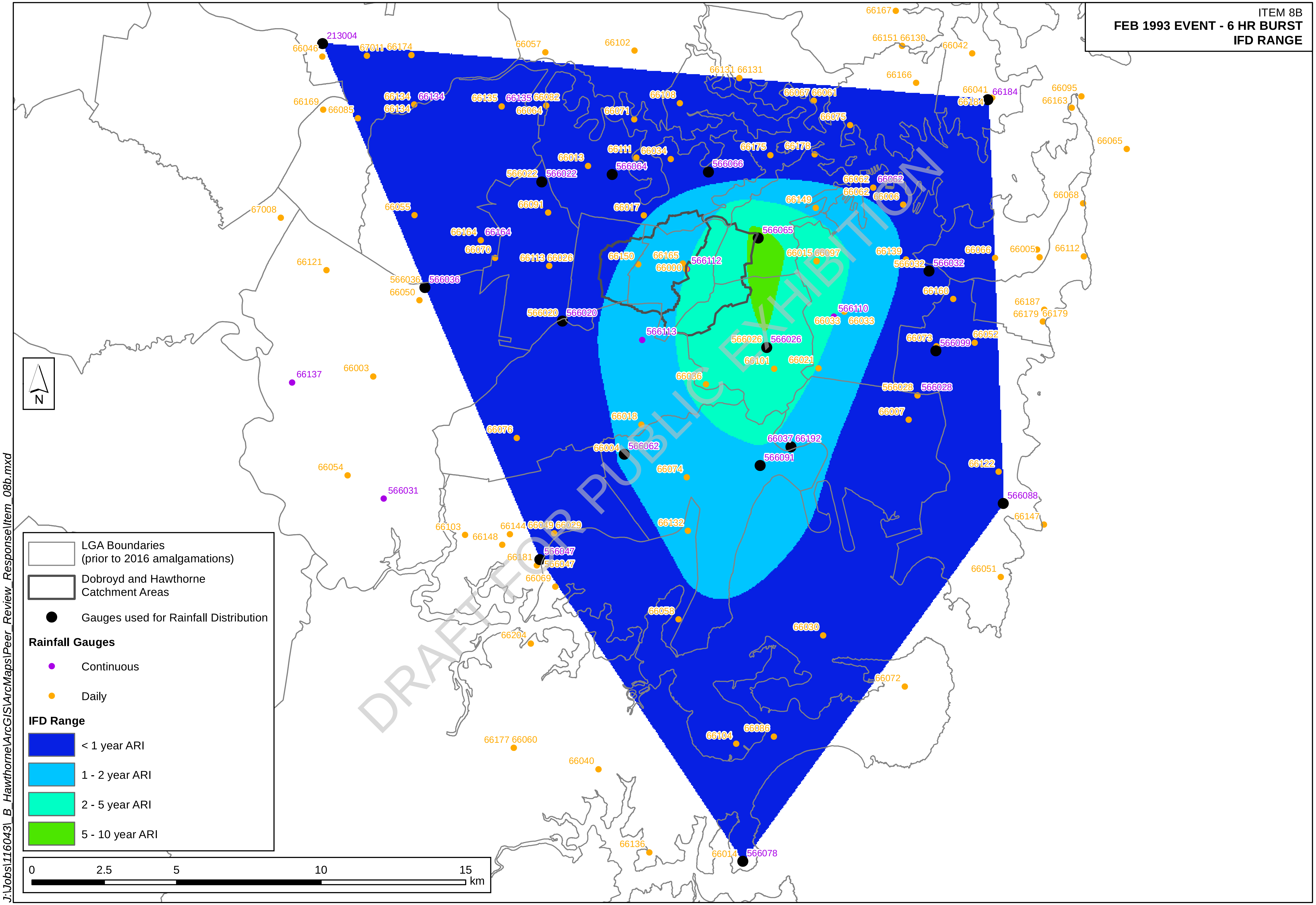

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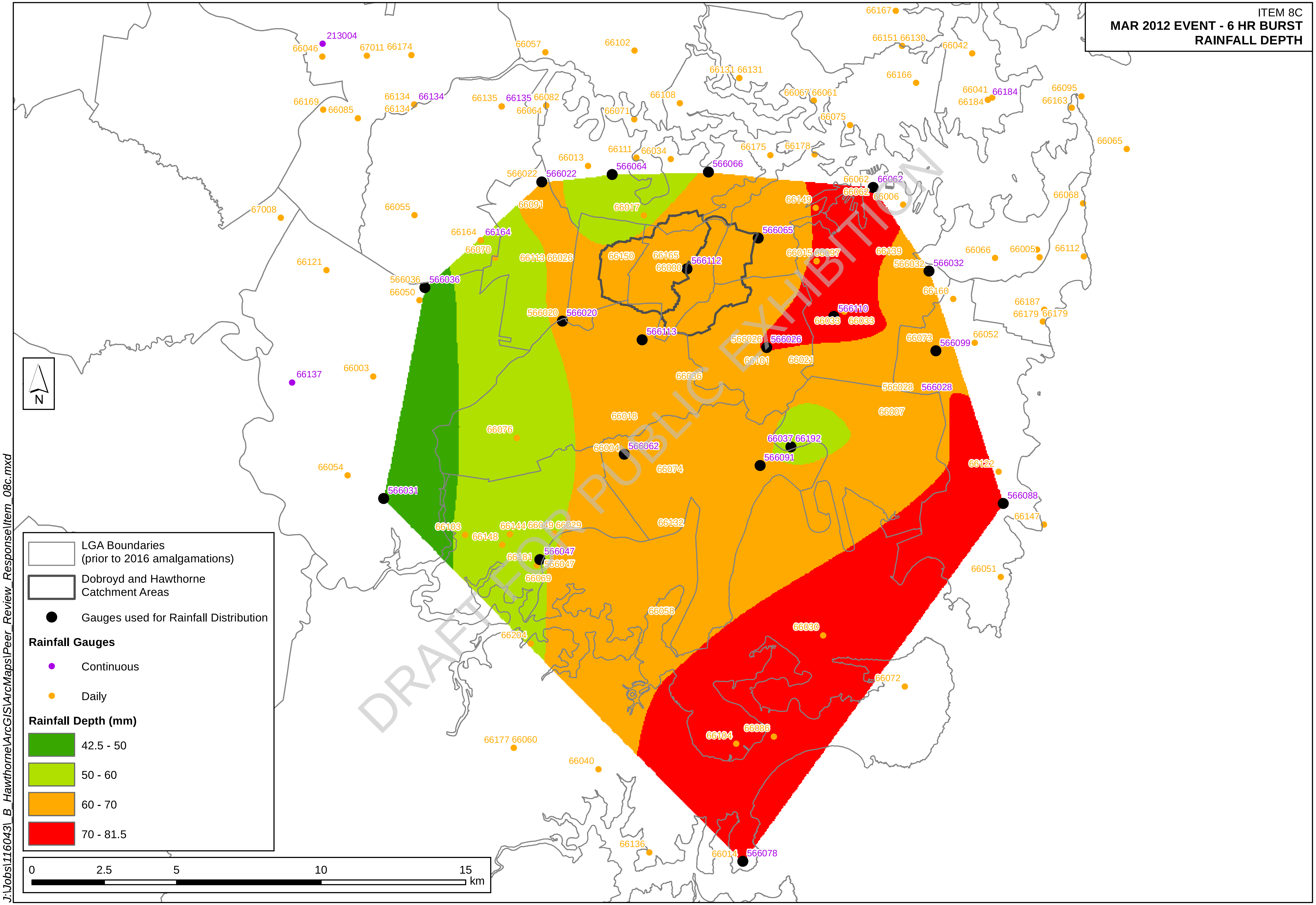
ITEM 8C
MAR 2012 EVENT - 6 HR BURST
RAINFALL DEPTH
DRAFT FOR PUBLIC EXHIBITION
LGA Boundaries
(prior to 2016 amalgamations)
Dobroyd and Hawthorne
Catchment Areas
Gauges used for Rainfall Distribution
Rainfall Gauges
Continuous
Daily
Rainfall Depth (mm)
42.5 - 50
50 - 60
60 - 70
70 - 81.5
0
2.5
5
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15
km
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66015 66097
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66160
66187
66179 66179
566020
566020
566110
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66037 66192
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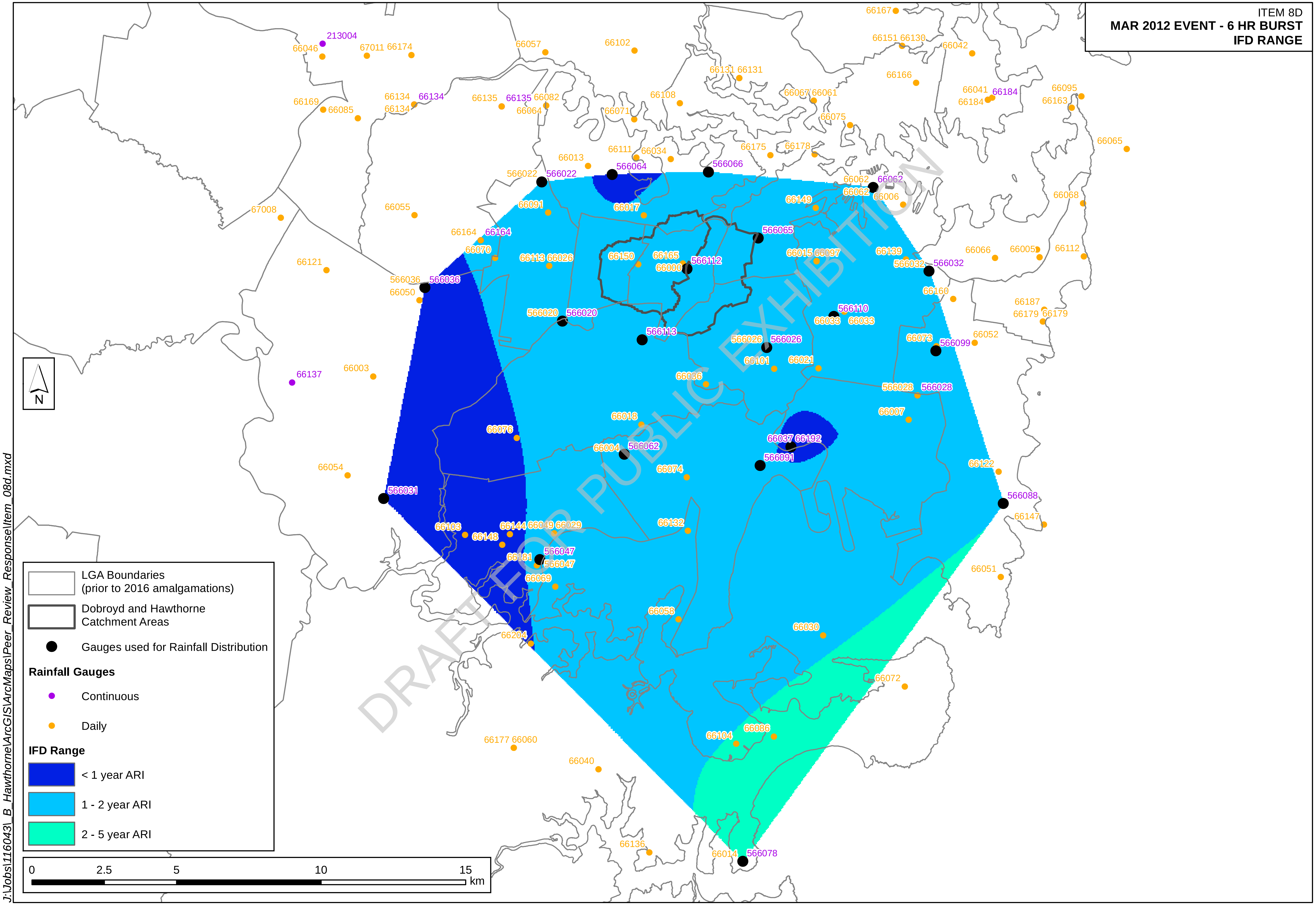
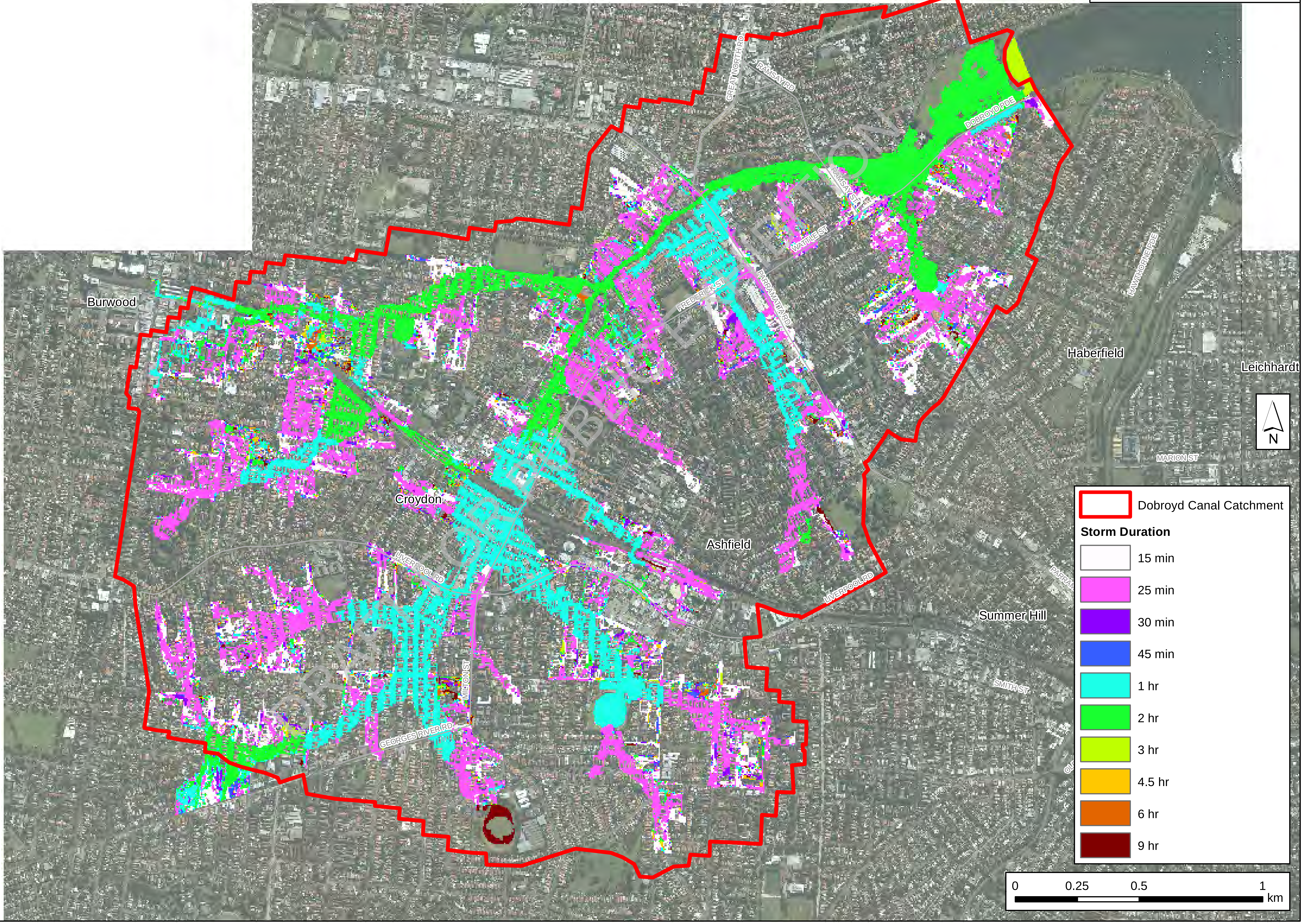
ITEM 8D
MAR 2012 EVENT - 6 HR BURST IFD RANGE



ITEM 13A

1% AEP CRITICAL DURATION EVENTS



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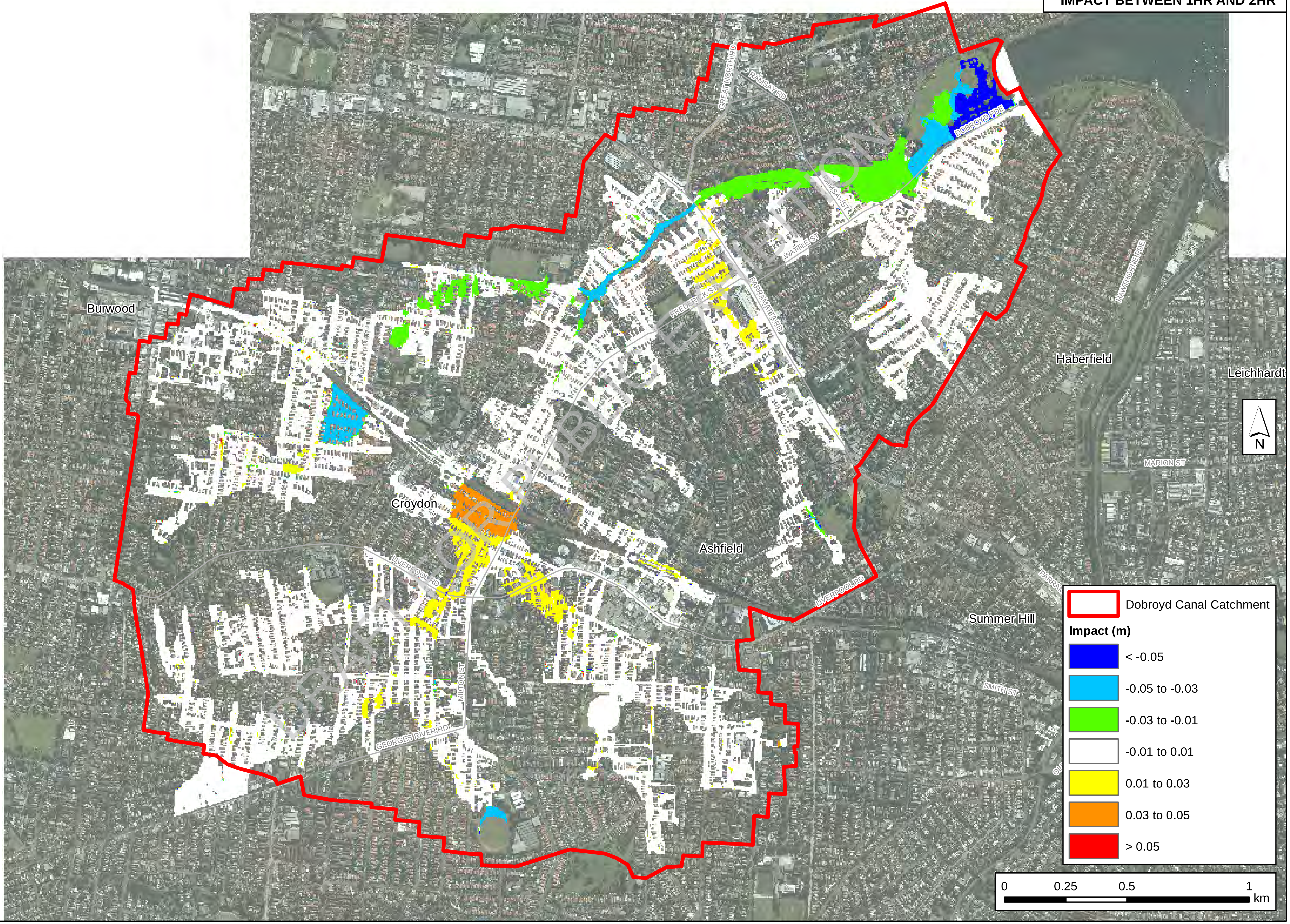
ITEM 13B

1% AEP CRITICAL DURATION
IMPACT BETWEEN 1HR AND 2HR



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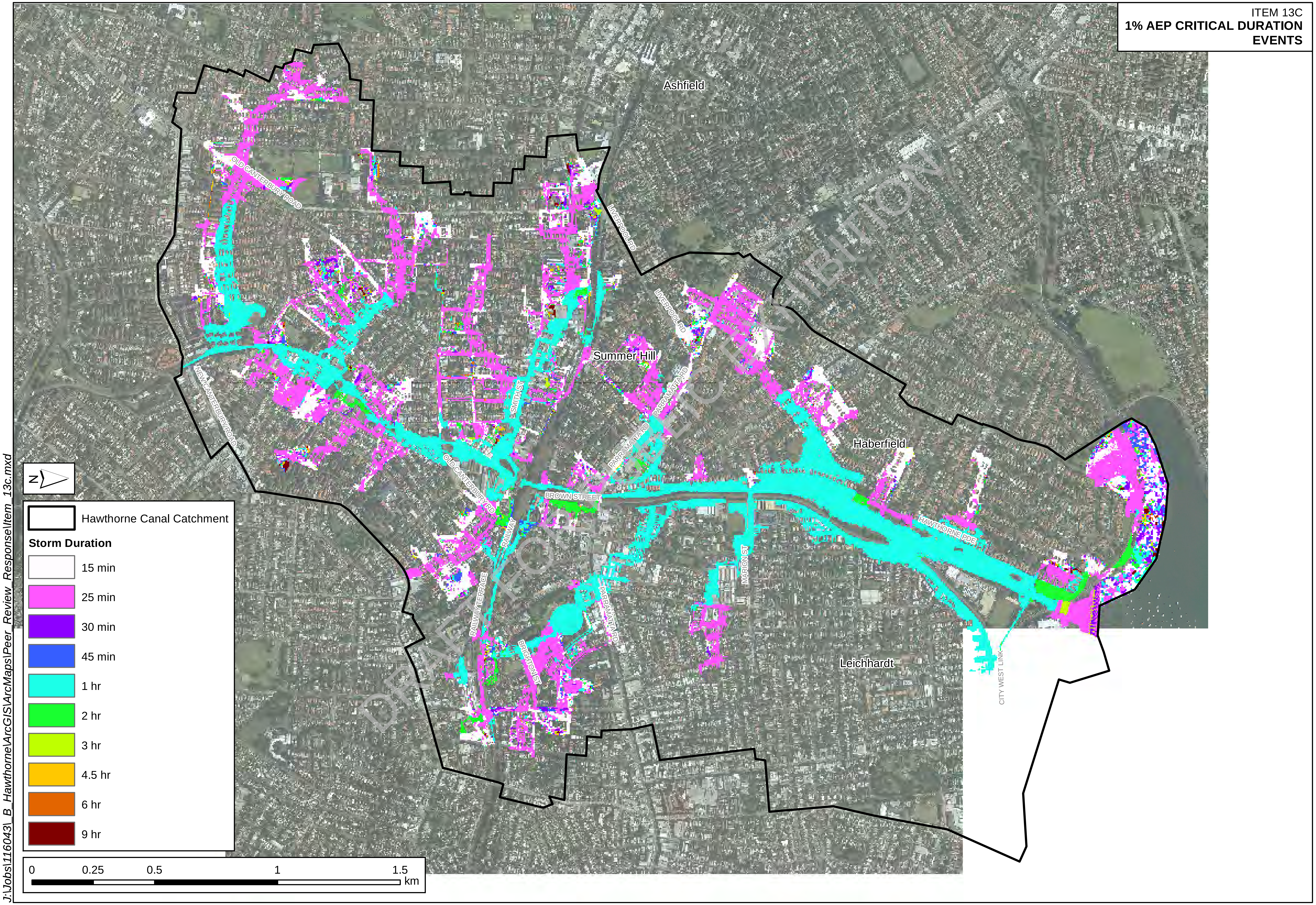
ITEM 13C
1% AEP CRITICAL DURATION EVENTS



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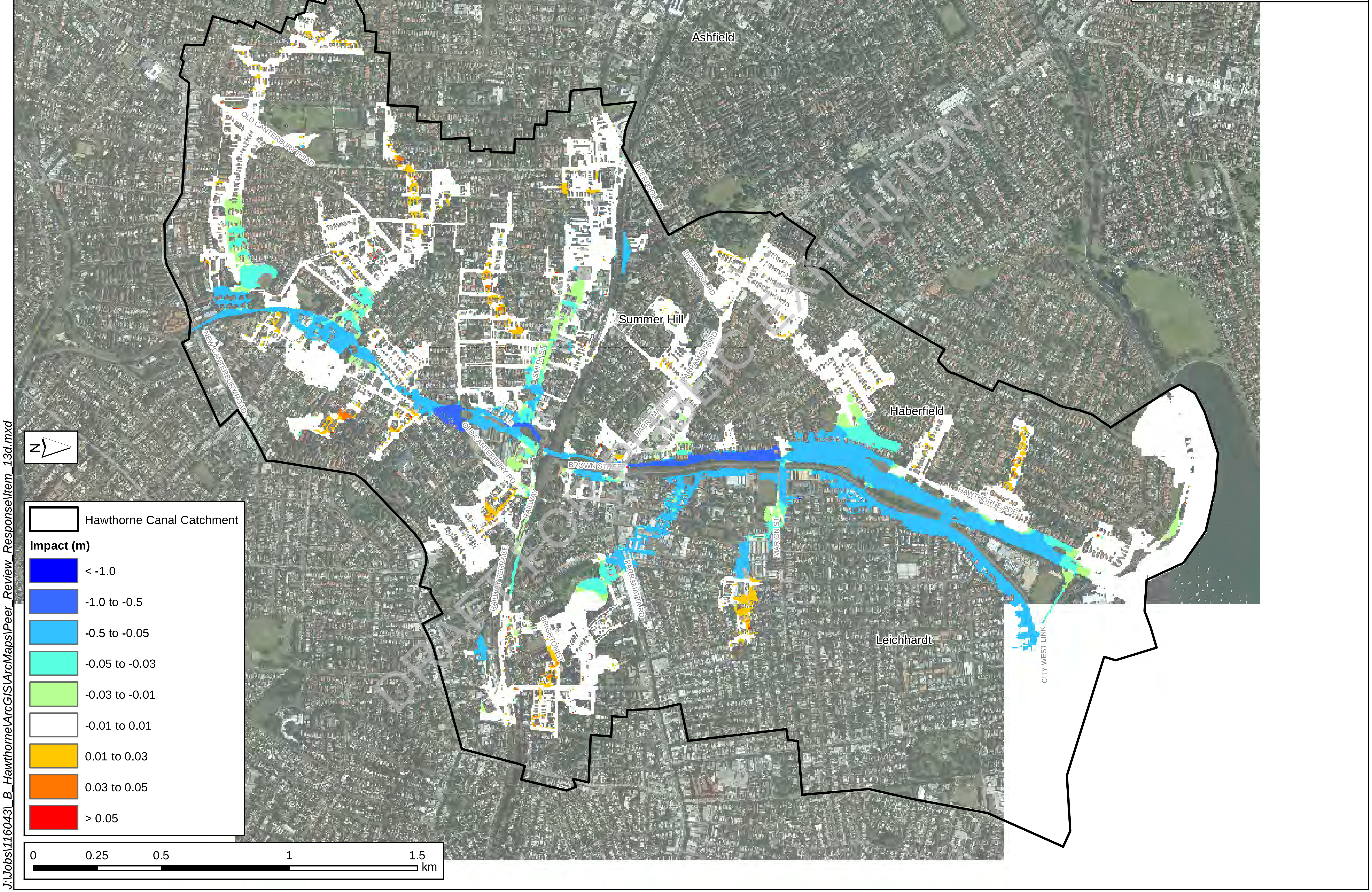
ITEM 13D

1% AEP CRITICAL DURATION IMPACT BETWEEN 25MIN AND 1HR



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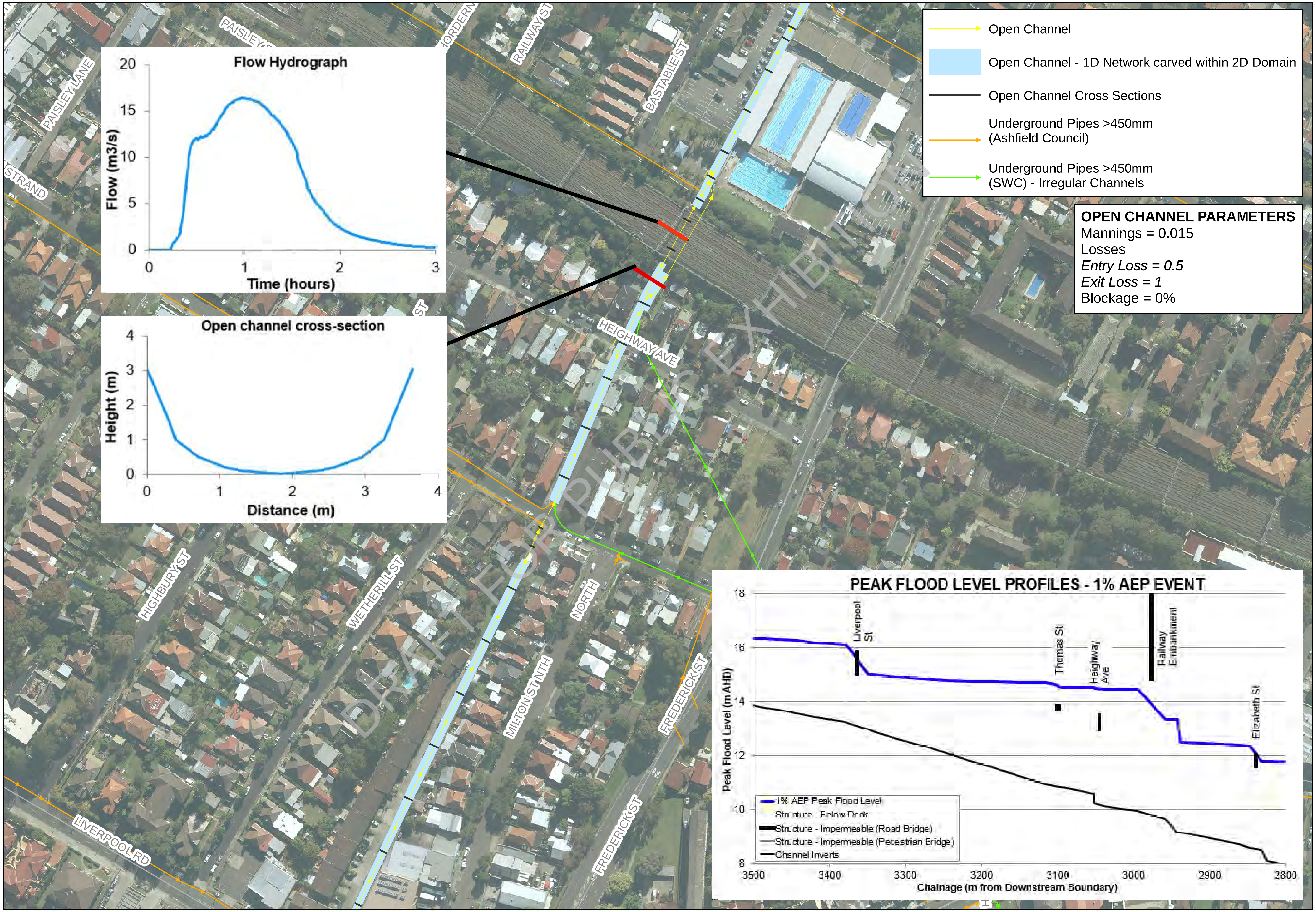
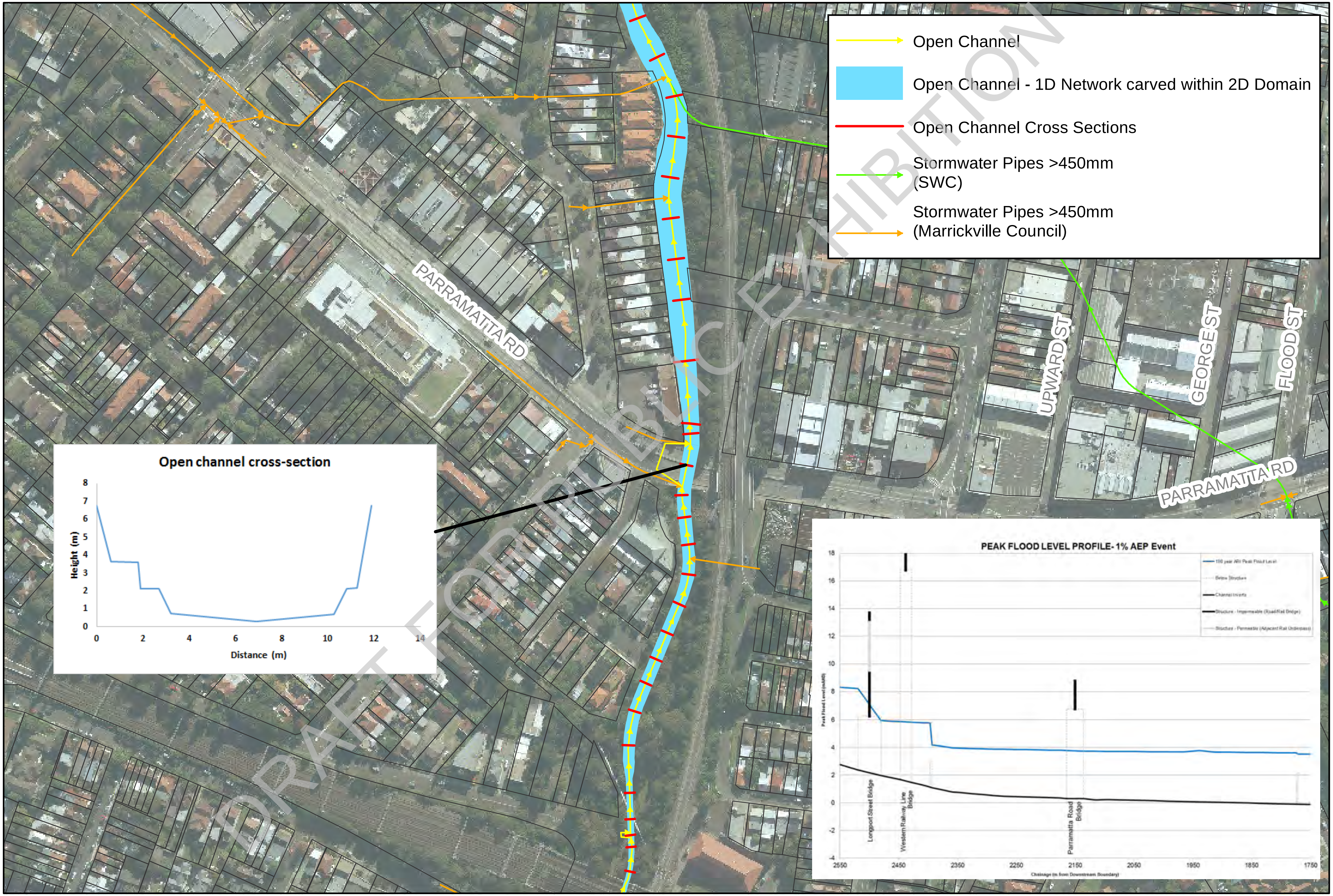
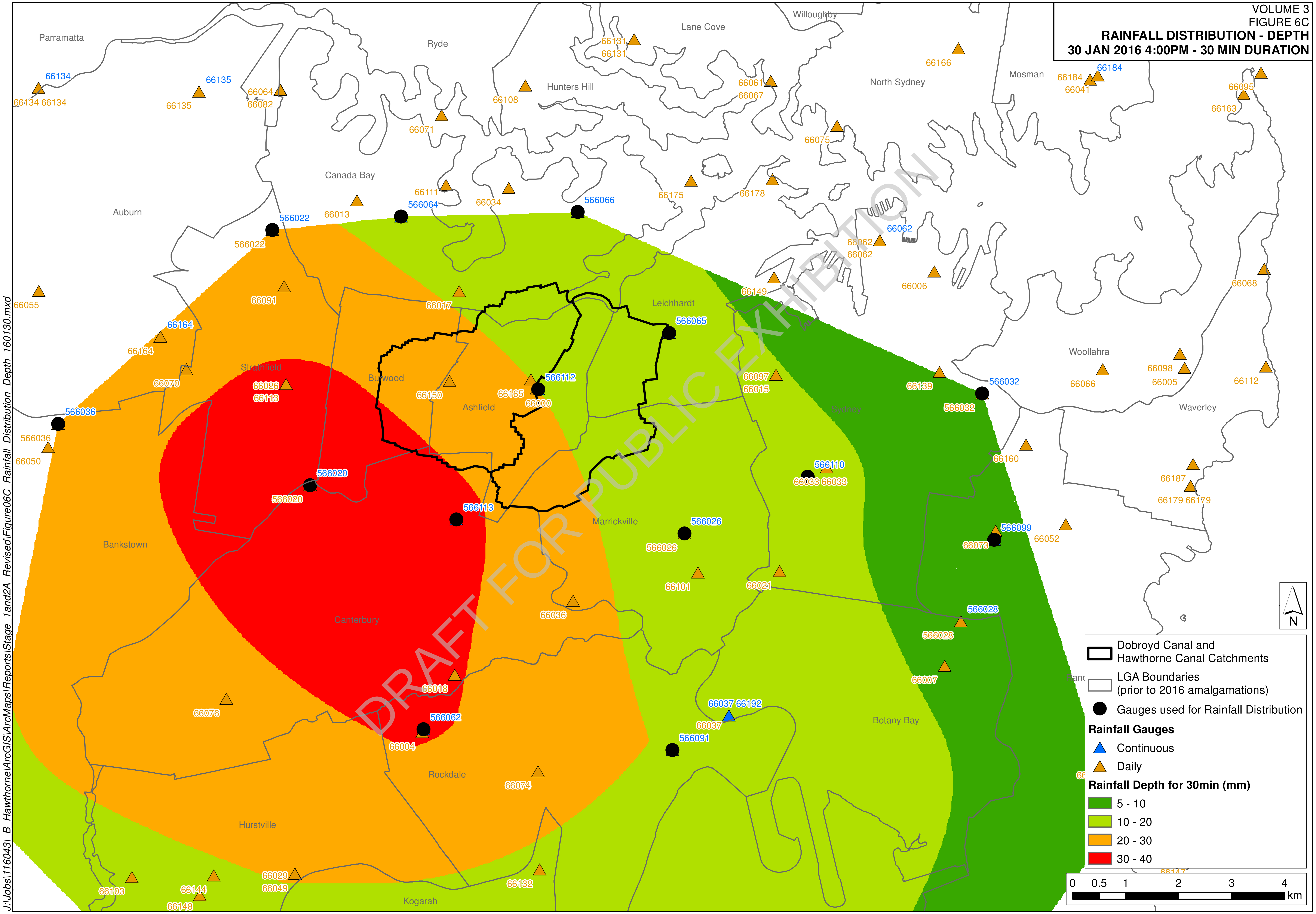


Open Channel
Open Channel - 1D Network carved within 2D Domain
Open Channel Cross Sections
Underground Pipes >450mm
(Ashfield Council)
Underground Pipes >450mm
(SWC) - Irregular Channels
OPEN CHANNEL PARAMETERS
Mannings = 0.015
Losses
Entry Loss = 0.5
Exit Loss = 1
Blockage = 0%
Flow Hydrograph
Flow (m3/s)
Time (hours)
0
5
10
15
20
0
1
2
3
Open channel cross-section
Height (m)
Distance (m)
0
1
2
3
4
PEAK FLOOD LEVEL PROFILES - 1% AEP EVENT
Peak Flood Level (m AHD)
Chainage (m from Downstream Boundary)
8
10
12
14
16
18
3500
3400
3300
3200
3100
3000
2900
2800
Liverpool St
Thomas St
Heighway Ave
Railway Embankment
Elizabeth St
1% AEP Peak Flood Level
Structure - Below Deck
Structure - Impermeable (Road Bridge)
Structure - Impermeable (Pedestrian Bridge)
Channel Inverts
PAISLEY
PAISLEY LANE
STRAND
RAILWAY ST
BASTABLE ST
HEIGHWAY AVE
HIGHBURY ST
WETHERILL ST
NORTH
MILTON ST NTH
FREDERICK ST
LIVERPOOL RD
DRAFT FOR PUBLIC EXHIBITION


Open Channel
Open Channel - 1D Network carved within 2D Domain
Open Channel Cross Sections
Stormwater Pipes >450mm (SWC)
Stormwater Pipes >450mm (Marrickville Council)
PARRAMATTA RD
UPWARD ST
GEORGE ST
FLOOD ST
PARRAMATTA RD
Open channel cross-section
Height (m)
Distance (m)
0
2
4
6
8
10
12
14
1
3
5
7
PEAK FLOOD LEVEL PROFILE- 1% AEP Event
Longport Street Bridge
Western Railway Line Bridge
Parramatta Road Bridge
2550
2450
2350
2250
2150
2050
1950
1850
1750
18
16
-2
-4
DRAFT FOR PUBLIC EXHIBITION

Appendix E

VOLUME 3
FIGURE 6C
RAINFALL DISTRIBUTION - DEPTH
30 JAN 2016 4:00PM - 30 MIN DURATION



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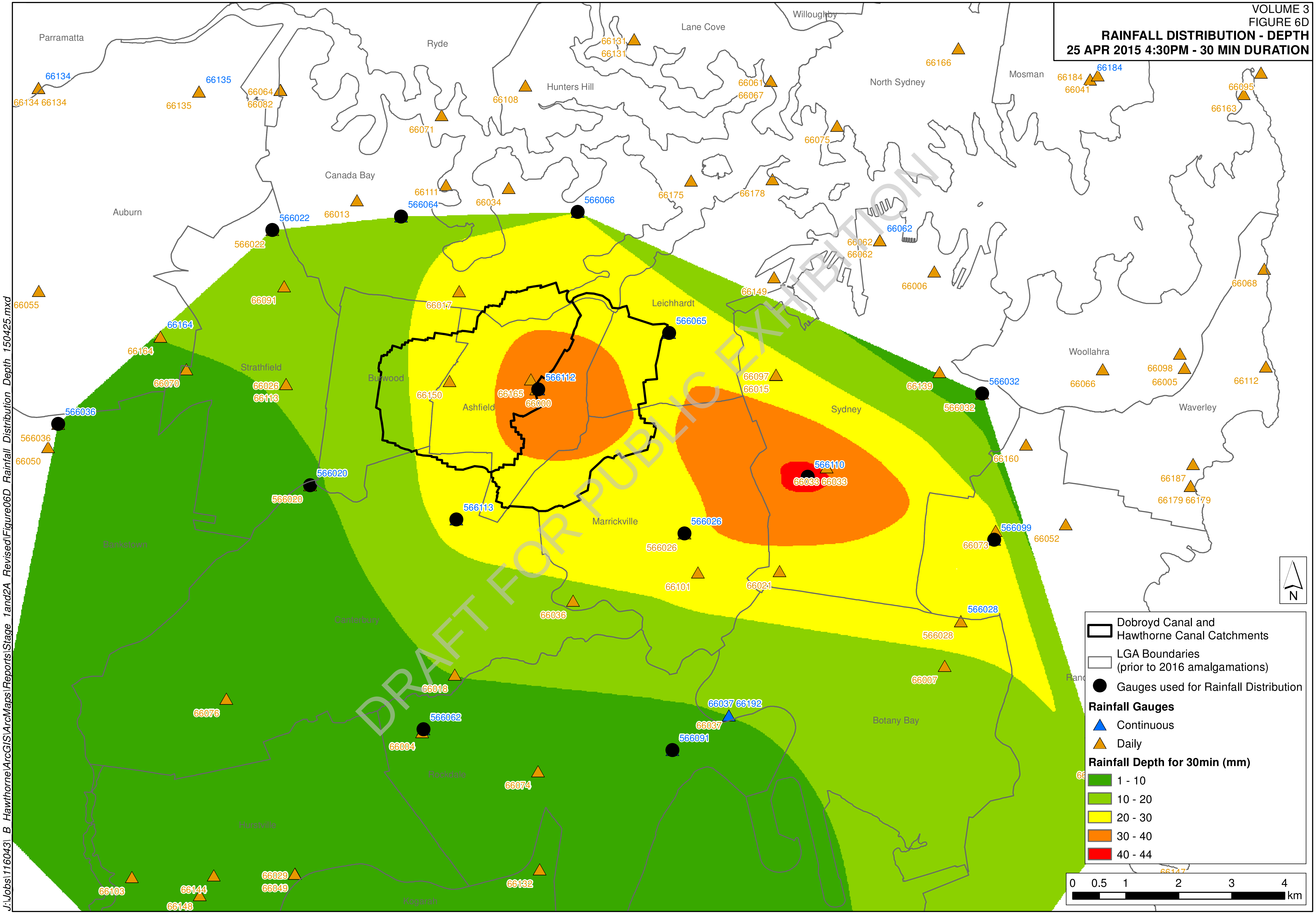
VOLUME 3
FIGURE 6D
RAINFALL DISTRIBUTION - DEPTH
25 APR 2015 4:30PM - 30 MIN DURATION



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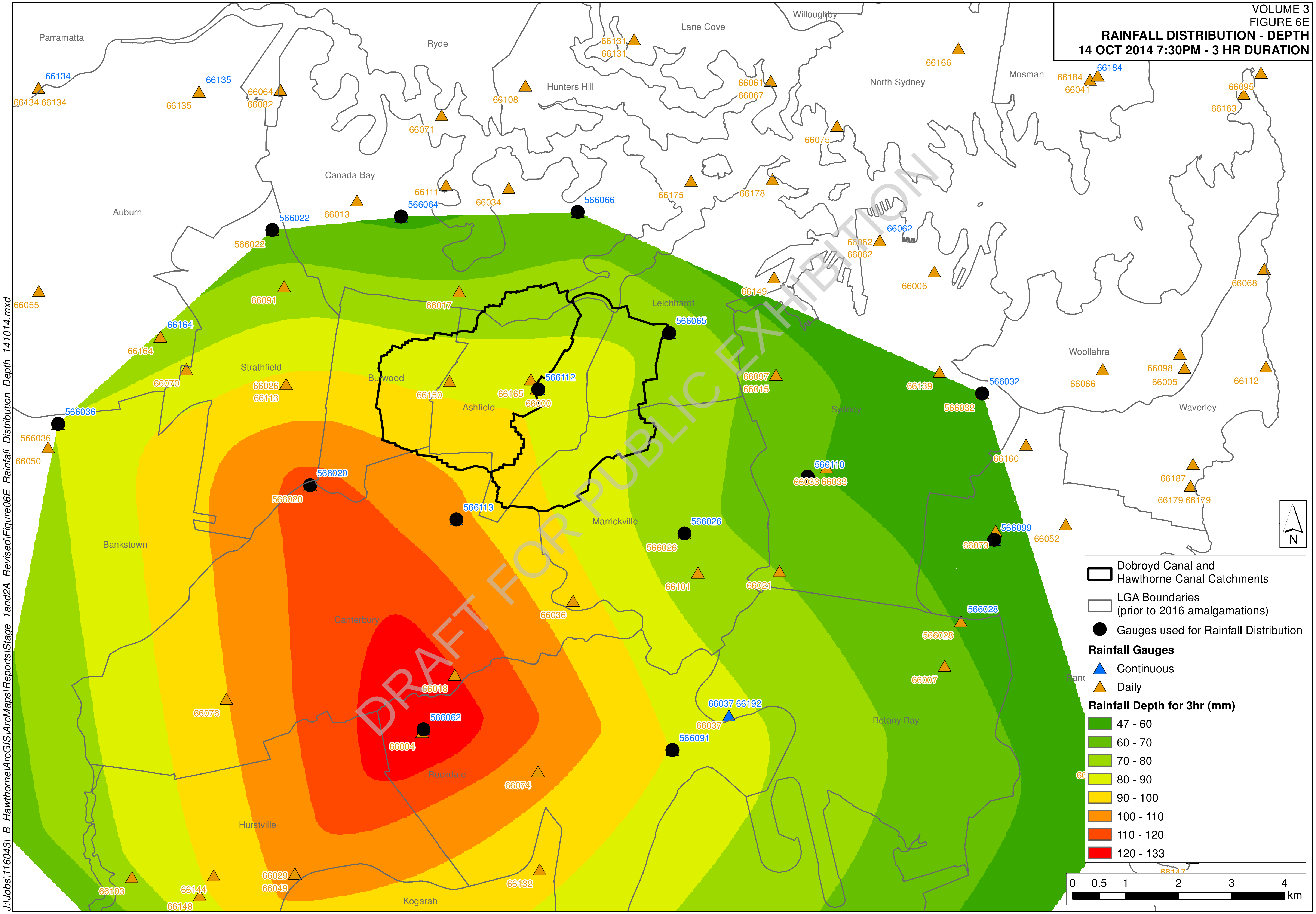
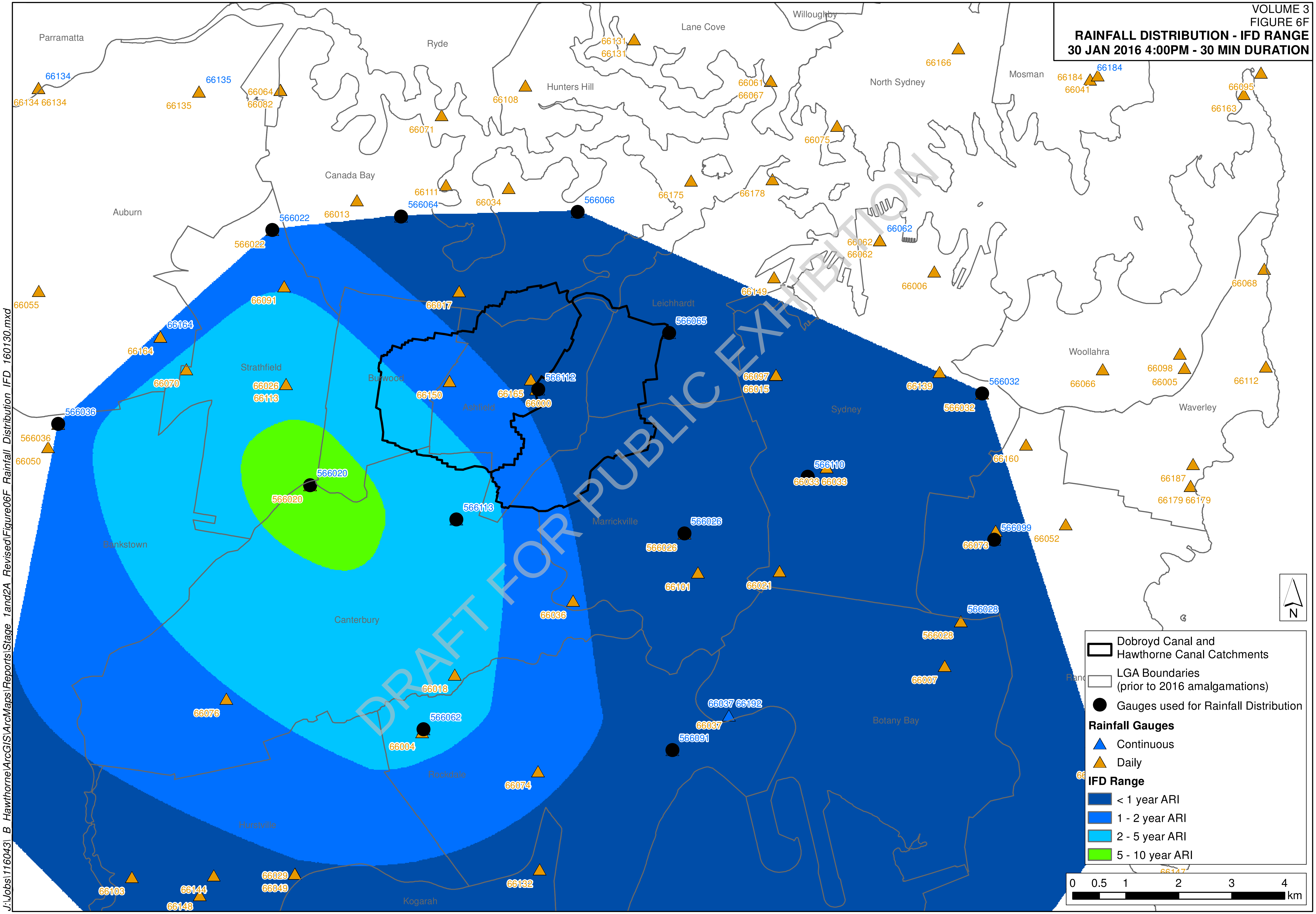
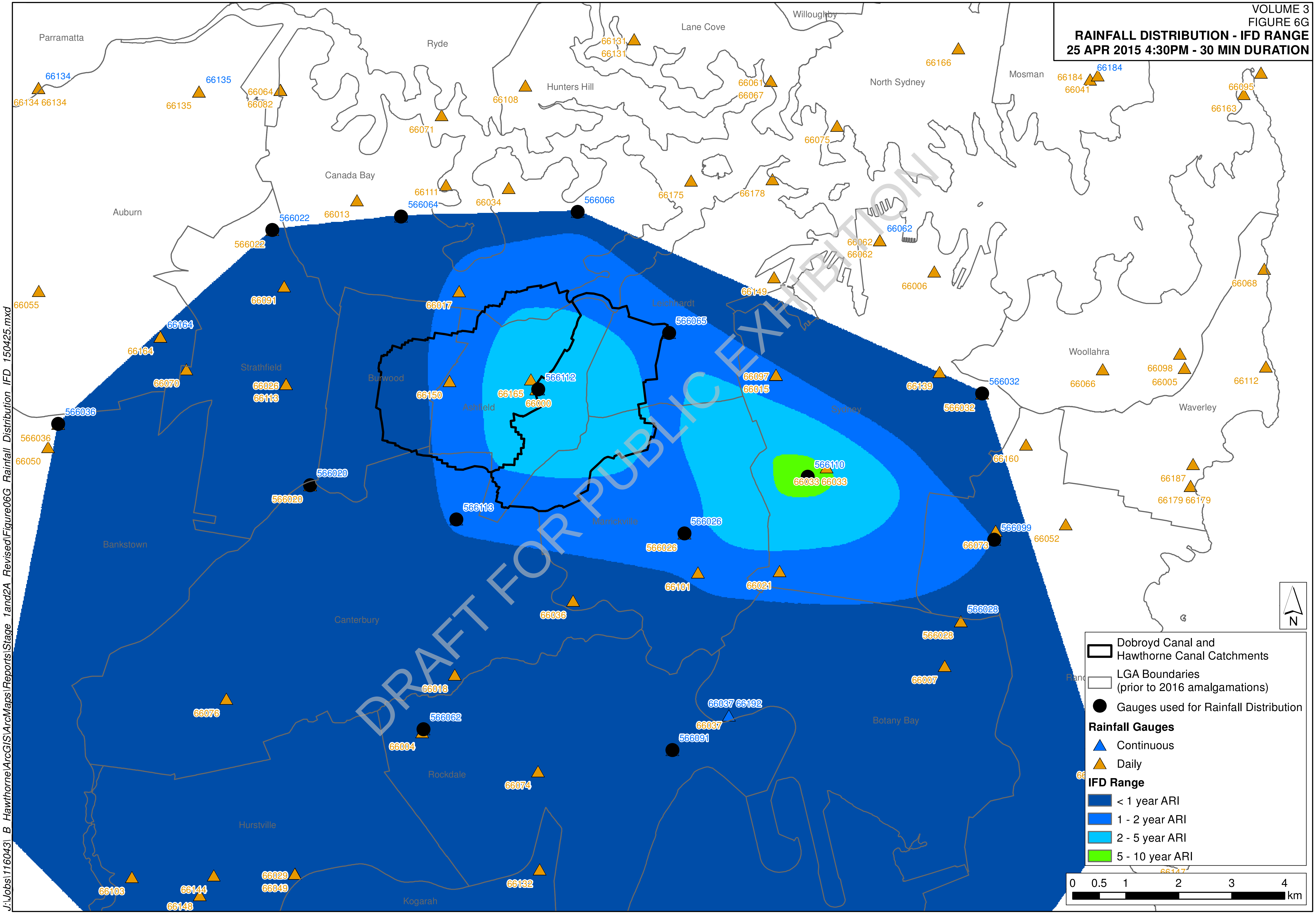
VOLUME 3
FIGURE 6E
RAINFALL DISTRIBUTION - DEPTH
14 OCT 2014 7:30PM - 3 HR DURATION




VOLUME 3
FIGURE 6F
RAINFALL DISTRIBUTION - IFD RANGE
30 JAN 2016 4:00PM - 30 MIN DURATION
Parramatta
Ryde
Lane Cove
Willoughby
Hunters Hill
North Sydney
Mosman
Canada Bay
Auburn
Leichhardt
Strathfield
Burwood
Ashfield
Woollahra
Sydney
Waverley
Marrickville
Bankstown
Canterbury
Rockdale
Hurstville
Kogarah
Botany Bay
DRAFT FOR PUBLIC EXHIBITION
Dobroyd Canal and Hawthorne Canal Catchments
LGA Boundaries (prior to 2016 amalgamations)
Gauges used for Rainfall Distribution
Rainfall Gauges
Continuous
Daily
IFD Range
< 1 year ARI
1 - 2 year ARI
2 - 5 year ARI
5 - 10 year ARI
0 0.5 1 2 3 4 km
N
J:\Jobs\116043\ B Hawthorne\ArcGIS\ArcMaps\Reports\Stage 1and2A Revised\Figure06F Rainfall Distribution IFD 160130.mxd



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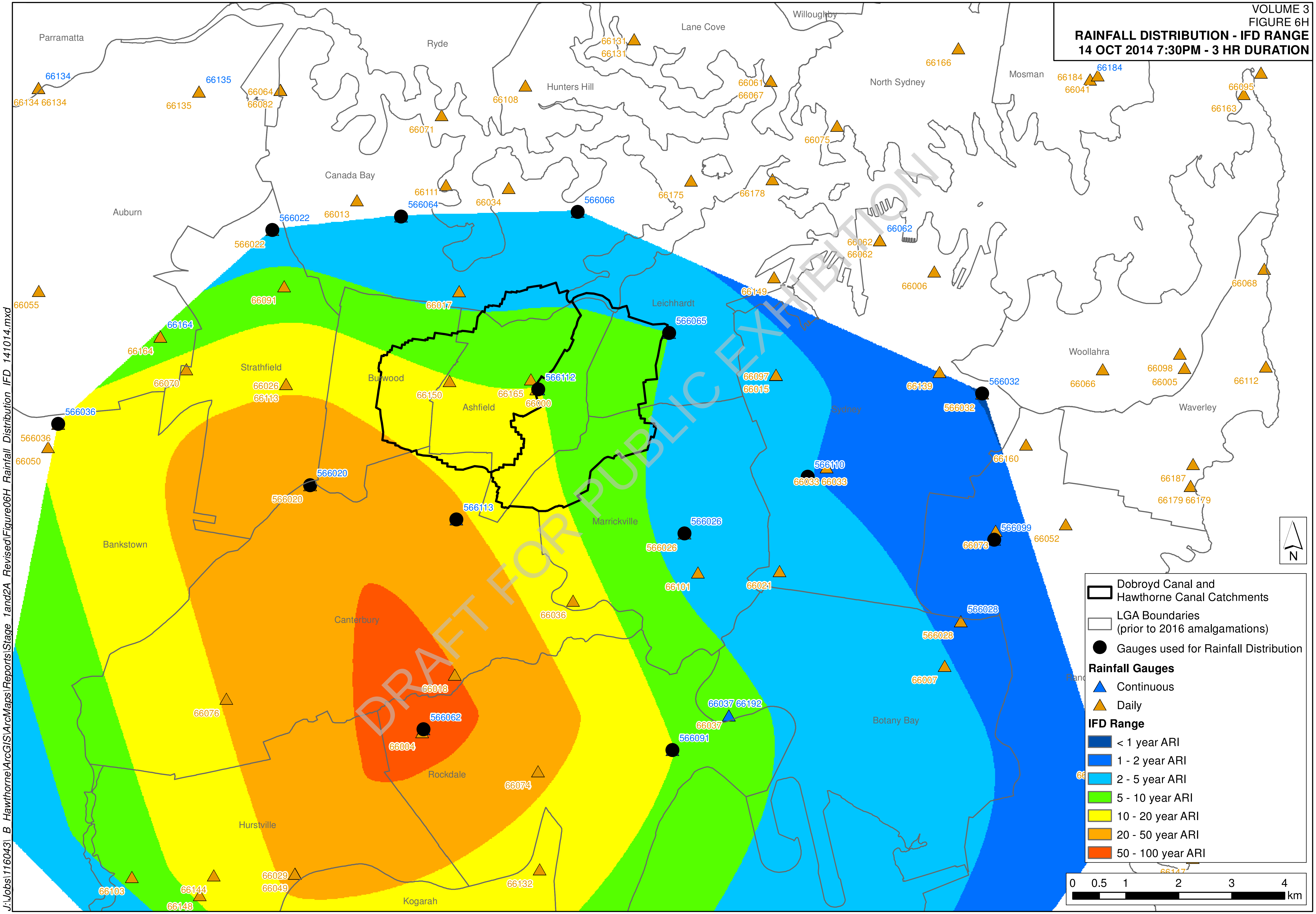

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Appendix F

Hotspot	Option ID	Location	Description	Assessment Stage [1]
Hawthorne Canal **Hotspot 01 – Queen Street, Ashfield**	FM0101A	Queen Street to Yeo Park	Pipe drainage upgrade	2 (App C Section B1.1)
	FM0101B	Queen Street To Yeo Park	Pipe drainage upgrade and above ground retention	2 (App C Section B1.2)
	FM0102A	Yeo Park (South Of Primary School)	Above ground detention basin	2 (App C Section B1.3)
	FM0103A	Elizabeth Avenue (Between Old Canterbury Road And Union Lane)	Pipe drainage upgrade	2 (App C Section B1.4)
	FM0104C	Arlington Recreation Ground Detention Basin	Above ground detention basin, with ramp for roadway access	2 (combined with 104D) (App C Section B1.5)
	FM0104D	Arlington Recreation Ground Detention Basin	Above ground detention basin, with ramp and floodgate for roadway access	2 (combined with 104C) (App C Section B1.5)
Hawthorne Canal **Hotspot 02 – Grosvenor Crescent, Summer Hill**	FM0401A	Grosvenor Cresent Under-Ground Detention Basin	Under-road detention basin	2 (App C Section B3.1)
	FM0403A & FM0403B	Grosvenor Cresent And Smith Street Flowpath Pipe Upgrade And Detention Basin	Pipe drainage upgrade, above ground detention basin and levee wall	3 (Section 10.2.9.1)
	FM0404A	Nowranie Street To Hawthorne Canal Drainage Upgrade	Pipe drainage upgrade	1
	FM0404B	Nowranie Street To Hawthorne Canal Drainage Upgrade	Pipe drainage upgrade	2 (App C Section B3.2)
	FM0404C	Nowranie Street To Hawthorne Canal Drainage Upgrade	Pipe drainage upgrade	3 (Section 10.2.9.2)
Hawthorne Canal **Hotspot 03 – Light Rail Track**	FM0201E	Gelding Street To Constitution Road Drainage Upgrade, Johnsons Park Detention Basin	Pipe drainage upgrade and above ground detention basin	1
	FM0301A	The Boulevarde To Hawthorne Canal Drainage Upgrade	Pipe drainage upgrade	1
	FM0301B	The Boulevarde To Hawthorne Canal Drainage Upgrade	Pipe drainage upgrade	2 (App C Section B2.1)
	FM0302A	The Boulevarde To Hawthorne Canal Underground Detention Basin	Under-ground detention basin and raingarden	2 (App C Section B2.2)
	FM0303A	Denison Road To Old Canterbury Road Drainage Upgrade	Pipe drainage upgrade	2 (App C Section B2.3)
	FM0303B	Denison Road To Old Canterbury Road Drainage Upgrade	Pipe drainage upgrade	2 (App C Section B2.4)
	FM0503A	Gordon Street, Trafalgar Street And Audley Street Drainage Upgrade	Pipe drainage upgrade	1
	FM0504A	Light Rail Training Centre Carpark Under Ground Detention Basin	Underground detention basin	1
Hawthorne Canal **Hotspot 04 – Sloane Street, Summer Hill/Haberfie ld**	FM0601A	Ashfield Park To Hawthorne Canal Drainage Upgrade	Pipe drainage upgrade	1
	FM0601B	Ashfield Park To Hawthorne Canal Drainage Upgrade	Pipe drainage upgrade	2 (App C Section B5.1)
	FM0601C	Ashfield Park to Daragh Lane drainage upgrade	Pipe drainage upgrade	1
	FM0602A	O'connor Avenue To Daragh Lane Drainage Upgrade	Pipe drainage upgrade	1
	FM0605A	Sloane Street Drainage Upgrade	Pipe drainage upgrade	2 (App C Section B5.2)
	FM0605B	Sloane Street Drainage Upgrade	Pipe drainage upgrade	2 (App C Section B5.2)
	FM0605C	Sloane Street drainage upgrade	Pipe drainage upgrade	3 (Section 10.2.9.4)

Hotspot	Option ID	Location	Description	Assessment Stage [(1)]
	FM0606A	Sloane Street Under-road Detention Basin	Under-road detention basin	2 (App C Section B5.3)
Hawthorne Canal **Hotspot 06 – Hawthorne Canal**	FM0701A	Dudley Street Down To Hawthorne Canal Upgrade	Pipe drainage upgrade	2 (App C Section B6.1)
	FM0702A	Waratah Street To City West Link Hawthorne Canal Upgrade	Levee	3 Combined with FM0702B (Section 10.2.9.5)
	FM0702B	Hawthrone Canal levee, Waratah St to City West Link	Levee	3 Combined with FM0702A (Section 10.2.9.5)
Hawthorne Canal **Other**	FM0501C	Petersham Park Above Ground Detention Basin	Above-ground detention basin, with spillway for larger events	2 (App C Section B4.1)
	FM0501D	Petersham Park Above Ground Detention Basin	Above-ground detention basin, with vehicle access maintained	2 (App C Section B4.1)
	FM0501E & FM0501F	Petersham Park Above Ground Detention Basin	Above-ground detention basin, with vehicle access ramp	2 (App C Section B4.1)
	FM0501G	Petersham Park Above Ground Detention Basin	Above-ground detention basin, with access moved to southern corner	3 (Section 10.2.9.3)
Dobroyd Canal **Hotspot 01 – Heighway Avenue, Croydon**	FM0102	Heighway Avenue Underground Detention Basin	Under-road detention basin	2 (App C Section A1.1)
	FM0102B	Heighway Avenue Underground Detention Basin	Under-road detention basin	2 (App C Section A1.2)
	FM0103	Milton Street North Underground Detention Basin	Under-road detention basin	2 (App C Section A1.3)
	FM0104	Heighway Avenue And Milton Street North Underground Detention Basin	Under-road detention basins	2 (App C Section A1.4)
	FM0106A	Duplication of Dobroyd Canal	Canal upgrade	2 (App C Section A1.5)
Dobroyd Canal **Hotspot 02 – Queen Street, Croydon**	FM0201	Queen Street Centenary Par Detention Basin	Above ground detention basin	2 (App C Section A2.1)
	FM0202	Queen Street Centenary Park Detention Basin	Above ground detention basin	2 (App C Section A2.1)
	FM0203	Queen Street Centenary Park Detention Basin	Above ground detention basin	2 (App C Section A2.1)
	FM0205	Queen Street Centenary Park Underground Detention Basin	Underground detention basin	2 (App C Section A2.2)
	FM0206A	Queen Street Centenary Park Underground Detention Basin	Above ground detention basin	2 (App C Section A2.1)
Dobroyd Canal **Hotspot 03 – Brown Street, Ashfield**	FM0301	Brown Street Drainage Upgrade	Pipe drainage upgrade	1
	FM0301B	Brown Street Drainage Upgrade	Pipe drainage upgrade	2 (App C Section A3.1)
	FM0302	Brown Street Drainage Upgrade	Pipe drainage upgrade	1
	FM0302B	Brown Street Drainage Upgrade	Pipe drainage upgrade	2 (App C Section A3.1)
	FM0303	Brown Street Underground Detention Basin	Under-road detention basin	2 (App C Section A3.2)
Dobroyd Canal **Hotspot 06 – Algie Park, Haberfield**	FM0601	Algie Park Above Ground Detention Basin	Detention basin upgrade	1
	FM0601B	Algie Park Above Ground Detention Basin	Detention basin upgrade with levee and drainage system	2 (App C Section A4.1)
	FM0602	Algie Park Under Ground Detention Basin	Underground detention basin	1

Hotspot	Option ID	Location	Description	Assessment Stage [1]
Dobroyd Canal **Other**	FM0701	Pratten Park Under Ground Detention Basin	Underground detention basin	2 (App C Section A5.1)
	FM0701B	Pratten Park Above Ground Detention Basin	Above ground detention basin	2 (App C Section A5.1)
	FM0702	Arthur Street Underground Detention Basin	Underground detention basin	2 (App C Section A5.2)
	FM0703	Pratten Park And Arthur Street Under Ground Detention Basin	Underground detention basin	3 (Section 10.2.9.6)

(2) Assessment Stages
1 – High Level
2 – Detailed Assessment
3 – Full Cost Benefit Assessment