THE UNIVERSITY OF SYDNEY

UNIVERSITY OF SYDNEY FLOOD RISK MANAGEMENT STAGE 1 – CAMPUS FLOOD STUDY REVIEW

FINAL REPORT

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Project University Of Sydney Flood Risk Management Stage 1 – Campus Flood Study Review	**Project Number** 113039
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UNIVERSITY OF SYDNEY FLOOD RISK MANAGEMENT STAGE 1 – CAMPUS FLOOD STUDY REVIEW

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EXECUTIVE SUMMARY

The University of Sydney (University) Campus Flood Study Review (Review) aims to define the existing flood behaviour on the University's Camperdown and Darlington campuses for a range of design events and assesses flood behaviour in development areas proposed by the Campus Improvement Programme (CIP). The study involves a review of the previously established City of Sydney models for the Blackwattle Bay Catchment Flood Study (Reference 1) and Johnstons Creek Catchment Flood Study (Reference 2), as they relate to the University Campus.

The specific aims of the Review are to:

- *update the existing models to reflect the current state of development on both University campuses;*
- *define flood behaviour in terms of flood levels, depths, velocities, and extents on the campuses, as well as flood hazard and hydraulic categories; and*
- *identify flood related development controls for the CIP.*

This study supports the State Significant Development Application for the CIP to the Minister for Planning and Infrastructure. It responds to the Director General requirements for a preliminary assessment of any flood risk on site and consideration of any relevant provisions of the NSW Floodplain Development Manual (2005), including potential effects of climate change, sea level rise and an increase in rainfall intensity.

The University campuses are located in two separate catchments: Blackwattle Bay Catchment and Johnstons Creek Catchment, which drain to Blackwattle Bay and Rozelle Bay respectively. The University land occupies about 50 hectares and is located at the upstream part of both catchments, meaning flooding is primarily from rain falling on the campus rather than flowing in from upstream areas. No historical records were available that described flooding on the campus beyond anecdotal evidence. It is known that rainfall causes frequent flooding in the wider catchments, downstream of the campuses.

The majority of the data required for the study have been collected as part of the two catchment-wide flood studies completed in 2012. Data included Airborne Laser Scanning (ALS), pits and pipes data, land use maps, rainfall data and flood marks. Additional data was obtained and used to refine the representation of the campuses, particularly recent developments, in the hydraulic models.

Design flood behaviour was determined through the use of the established hydrologic/hydraulic models (one for each catchment). The direct rainfall on grid approach has been used in the hydrodynamic modelling package TUFLOW which negates the need for a separate hydrologic model. The models were reviewed and updated as part of this study.

Design rainfall data from the Bureau of Meteorology and design rainfall patterns from Australian

Rainfall and Runoff (1987) were obtained and input to the modelling procedure to obtain the design flood data. Detailed mapping was undertaken for a range of design events (5, 20 and 100 year ARI, and the Probable Maximum Flood) with the results provided as maps showing:

- Peak flood depths and level contours for all design flood events, Figure 8 - Figure 11 (Appendix 1);
- Peak flood velocity for all design flood events, Figure 12 - Figure 15 (Appendix 1);
- Provisional flood hazard categorisation for all design flood events, Figure 16 - Figure 19 (Appendix 1); and
- Preliminary flood hydraulic categorisation for all design flood events, Figure 20 - Figure 23 (Appendix 1).

The main outcomes of this study are:

- full documentation of the methodology and results;
- preparation of depth, velocity, hazard and extent maps for the University Campus;
- identification of flooding hot spots; and
- the modelling will be the basis for assessing impacts of developments proposed by the CIP.

As part of this Flood Study Review, suitable mitigation works are also examined but would be assessed in more detail in future assessments.

1. INTRODUCTION

This Campus Flood Study Review (Review) has been prepared by WMAwater (formally Webb, McKeown & Associates) on behalf of the University of Sydney (University). The main objective of this study is to define the existing flood behaviour on the University of Sydney's Camperdown and Darlington campuses for a range of design events. This includes a review of the existing flood studies carried out for the area, namely Blackwattle Bay Catchment Flood Study (Reference 1) and Johnstons Creek Catchment Flood Study (Reference 2). The findings in this report provide information to inform the University and its Campus Improvement Programme 2014 - 2020 with regards to managing existing and future flood risk within the study area.

1.1. Objectives

The information and results obtained from this study will define existing flood behaviour within the University's Camperdown and Darlington campuses and provide a firm basis for the development of a subsequent Campus Flood Risk Management Study and Plan as well as the flood impact assessment of the CIP.

In addition to defining the flood behaviour (5, 20 and 100 year ARI and the Probable Maximum Flood (PMF)) on both campuses, the study was developed to:

- Define flood behaviour in terms of flood levels, depths, velocities, and flood extents within the study area;
- Provide provisional flood hazard and flood extent mapping (for all design events modelled);
- Consider existing flood risk and recommend a suitable flood mitigation strategy for the study area; and
- Identify appropriate development controls to mitigate flooding in developments proposed by the CIP.

1.2. Study Area

Referring to Figure 1 (Appendix 1), the University's main campuses are located in Sydney's inner city suburbs of Camperdown and Darlington, and border Glebe, Chippendale, Newtown and Forest Lodge. Both campuses lie within the City of Sydney Local Government Area (LGA) over two separate catchments. The area south of City Road and east of Eastern Avenue is located at the upstream part of the Blackwattle Bay catchment which discharges to Blackwattle Bay, while the remaining area west of Eastern Avenue and north of City Road/King St forms part of the Johnstons Creek Catchment which discharges to Rozelle Bay. The University land occupies about 50 hectares within both catchments. The campuses have undergone much development and comprise multi-storey buildings, small streets, pedestrian thoroughfares, and landscaped sports fields.

Floodwaters from the campuses are conveyed downstream via overland flow paths such as roads and via a subsurface pit and pipe network. For the campus area within the Johnstons Creek catchment, the subsurface drainage feeds to the pipe junction north of St John's Oval, while runoff from the campus area within the Blackwattle Bay catchment drains to Victoria Park, City Road and Shepherd St in Chippendale.

A number of locations within the Blackwattle Bay and Johnstons Creek catchments are flood liable. This flood liability mainly relates to the nature of the topography within the study area as well as the capacity of drainage assets. The location of the campuses at the top of the two catchments means flooding is primarily from rainfall over the campus area as there is no 'upstream' catchment. However, the extensive development of the area from its natural state means buildings often obstruct flow, the ground perviousness has been reduced and natural flow paths have been built over – all typical in an urban catchment. Furthermore, the playing fields in the University act as retarding basins in flood events. The existing topography of the catchments is shown in Figure 2 (Appendix 1).

Currently, several major developments have been planned and approved for the Camperdown and Darlington campuses. These include the Australian Institute for Nanoscience (AIN), the Abercrombie Precinct Redevelopment, the Sports and Aquatic Centre Expansion and the Charles Perkins Building. Recently completed developments include Cadigal Green, Darlington Walk, the Jane Foss Russell Building, the new Faculty of Law Building, and upgrade of Eastern Avenue.

The CIP identified 5 key precincts for development by the University as follows:

- Life Sciences Precinct;
- Health Precinct;
- Merewether Precinct;
- City Road Precinct; and
- Engineering Precinct.

1.3. Catchment History

The Johnstons Creek and Blackwattle Bay catchments were both first settled in the early 1800s. The catchments are now almost completely developed as urban land, and the natural flow paths and creeks have been converted into a constructed drainage system of open channels and sub surface elements. The effect of development was a significant increase in peak runoff rates and volumes combined with a restriction in the conveyance capacity of overland flow paths.

The University of Sydney was established in 1850 and was located at its current site by 1859, on what was previously Grose Farm. Early buildings included the Great Hall and the surrounding buildings. The University followed the trend of development of the surrounding suburbs, expanding west in the direction of Parramatta Road, south west in the direction of King Street, and south towards City Road. Victoria Park was part of the Grose Farm property and was designated as a park in 1870.

While no data is available that describes historical flooding on the University campuses, historical records for the surrounding areas show a long history of flooding. Records show floods have occurred in 1949, 1961, 1975, 1984, 1991, 1998, 2001 and 2011. Rainfall records for these events show that relatively low intensity rainfall (between 2 and 5 year ARI) can cause flooding in localised areas.

1.4. Drainage System

Both campuses are serviced by the University owned minor drainage network which feeds into the Sydney Water Corporation (SWC) owned trunk drainage systems in Blackwattle Bay and Johnstons Creek catchments. For the campus area within the Blackwattle Bay catchment, the Eastern Avenue drainage connects to that of City Road, while the area south of City Road is drained by four separate networks which all connect to drainage on Shepherd Street. Also, a small section east of the Great Hall connects to the drainage on Broadway. For the remaining campus which drains to Johnstons Creek, an extensive subsurface drainage network culminates in a culvert underneath Parramatta Road that connects to the Orphan School Creek Branch. There are three sub-branches that connect to this point: ‘Hockey Field’, ‘Physics School’ and ‘St Andrews’. The drainage networks are shown in Figure 3 (Appendix 1).

2. AVAILABLE DATA

2.1. Background

Various items of data as well as reports salient to the study have been collected and reviewed. Most datasets were sourced from City of Sydney (Council) as part of the Blackwattle Bay and Johnstons Catchments Flood Studies (References 1 and 2). Additional data covering details of the campuses were provided by the University which were then incorporated into the existing models to provide a more detailed and accurate representation of the study area in both catchments.

2.2. Survey Data

Airborne Laser Scanning (ALS) data of the site was obtained from Council to define ground surface elevations of both catchments. The provided ALS data was a combination of data collected in 2007 and 2008 with a 1.3 m average point separation. The ALS provides ground level spot heights from which a Digital Elevation Model (DEM) can be constructed. For well defined points mapped in areas of clear ground, the expected nominal point accuracies (based on a 68% confidence level) are ±0.15 m (vertical accuracy). When interpreting the above, it should be noted that the accuracy of the ground definition can be adversely affected by the nature and density of vegetation and/or the presence of steeply varying terrain. This data formed the foundation of the 2D hydraulic model build process.

The ALS data was supplemented in areas where the ground elevation had changed since 2008 on the campus. Areas where the topography has been updated include:

- Eastern Avenue - contour plans were provided detailing the new ground elevation;
- The vicinity of the new Faculty of Law building – up-to-date ground elevation was given as spot heights;
- Cadigal Green and Darlington Walk - the recently renovated area was described by spot heights; and
- A small section of raised land immediately north-west of the Bruce Williams Pavilion.

2.3. Campus Developments

Data describing developments on the campuses were also used to update the building outlines used in the hydraulic model. The following buildings were updated with the locations shown in Figure 4 (Appendix 1):

- Jane Foss Russell Building;
- Faculty of Law Building;
- Australian Institute of Nanoscience Building;
- Charles Perkins Building;
- Sports and Aquatic Centre;

- Abercrombie Precinct.

2.4. Pit and Pipe Data

Pit and pipe data was supplied by Council for the wider catchment, and supplemented with a smaller dataset provided by the University. The physical details included:

- coordinates of each pit;
- linkage between pits;
- pipe dimensions; and
- pit details (type of pit, inlet type and dimensions and depth to invert).

A preliminary schematisation of the pit and pipe network of the University campuses was carried out by combining Council's database with a survey of the stormwater drainage network undertaken in 2002. Further details were added based on a site inspection. Pipe sizes and pit inverts were estimated based on adjacent pipes in some areas where there was insufficient data. Figure 3 (Appendix 1) shows the layout of the campus pit and pipe networks.

The pit and pipe network was also modified to correspond to recent and ongoing developments on the campuses. Pits and pipes under Eastern Avenue, the new Faculty of Law Building, the Charles Perkins Building, the new Sports Hall, the Australian Institute of Nanoscience, Cadigal Green and Darlington Walk were all modified based on plans of each area (either as-con drawings or design plans). Underground retarding basins were installed at both the Cadigal Green and Darlington Walk areas.

2.5. Design Rainfall Data

Design rainfalls were obtained from the Bureau of Meteorology (BoM) and temporal patterns were obtained from Australian Rainfall and Runoff (Reference 3). The Intensity-Frequency-Duration (IFD) data for the two catchments are provided in Table 1 and Table 2.

Table 1: IFD Data for Blackwattle Bay Catchment

Location: 33.875S 151.200E NEAR.. Blackwattle Bay Issued: 25/10/2011

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

	Average Recurrence Interval						
Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	101	129	163	183	209	243	269
6Mins	94.3	121	153	172	196	228	252
10Mins	77.2	99.1	127	142	164	191	212
20Mins	56.6	73.1	94.8	107	124	146	163
30Mins	46.0	59.7	78.0	88.8	103	122	136
1Hr	31.2	40.5	53.5	61.2	71.2	84.4	94.5
2Hrs	20.3	26.4	34.9	39.9	46.5	55.1	61.8
3Hrs	15.6	20.3	26.7	30.6	35.6	42.2	47.3
6Hrs	9.90	12.8	16.9	19.2	22.3	26.4	29.6
12Hrs	6.34	8.21	10.7	12.2	14.2	16.8	18.7
24Hrs	4.12	5.33	6.98	7.95	9.22	10.9	12.2
48Hrs	2.64	3.42	4.49	5.12	5.94	7.02	7.85
72Hrs	1.97	2.55	3.33	3.80	4.41	5.21	5.82

(Raw data: 40.84, 8.2, 2.55, 85.87, 16.75, 5.22, skew=0.00, F2=4.29, F50=15.86) © Australian Government, Bureau of Meteorology

Table 2: IFD Data for Johnstons Creek Catchment

Location: 33.875S 151.175E NEAR.. Johnstons Creek Catchment Issued: 21/11/2011

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

	Average Recurrence Interval						
Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	98.7	126	161	180	206	240	266
6Mins	92.4	118	151	169	194	225	250
10Mins	75.7	97.3	125	140	161	188	209
20Mins	55.4	71.6	93.0	106	122	144	160
30Mins	45.1	58.5	76.6	87.2	101	119	133
1Hr	30.5	39.7	52.4	60.0	69.8	82.8	92.8
2Hrs	19.9	25.9	34.2	39.2	45.7	54.2	60.8
3Hrs	15.3	19.9	26.3	30.1	35.1	41.6	46.6
6Hrs	9.74	12.7	16.7	19.0	22.1	26.2	29.3
12Hrs	6.26	8.12	10.7	12.1	14.1	16.6	18.6
24Hrs	4.08	5.28	6.93	7.90	9.16	10.8	12.1
48Hrs	2.62	3.39	4.45	5.08	5.90	6.99	7.81
72Hrs	1.95	2.53	3.32	3.79	4.39	5.19	5.81

(Raw data: 39.98, 8.11, 2.53, 84.19, 16.64, 5.2, skew=0.00, F2=4.29, F50=15.86) © Australian Government, Bureau of Meteorology

Probable Maximum Precipitation (PMP) rainfall depths used to determine the Probable Maximum Flood (PMF) were obtained from Reference 4 using the generalised short-duration method. The maximum duration for which the method is applicable in the region is 6 hours. The parameters used for estimating the PMP are:

- Terrain classification: rough;
- Adjustment for catchment elevation (EAF): 1;
- Moisture Adjustment Factor (MAF): 0.7; and
- Ellipses enclosing the catchment: A and B (refer to Reference 4 for further explanation of ellipsoid selection and References 1 and 2 for the PMP rainfall depths derived for both catchments).

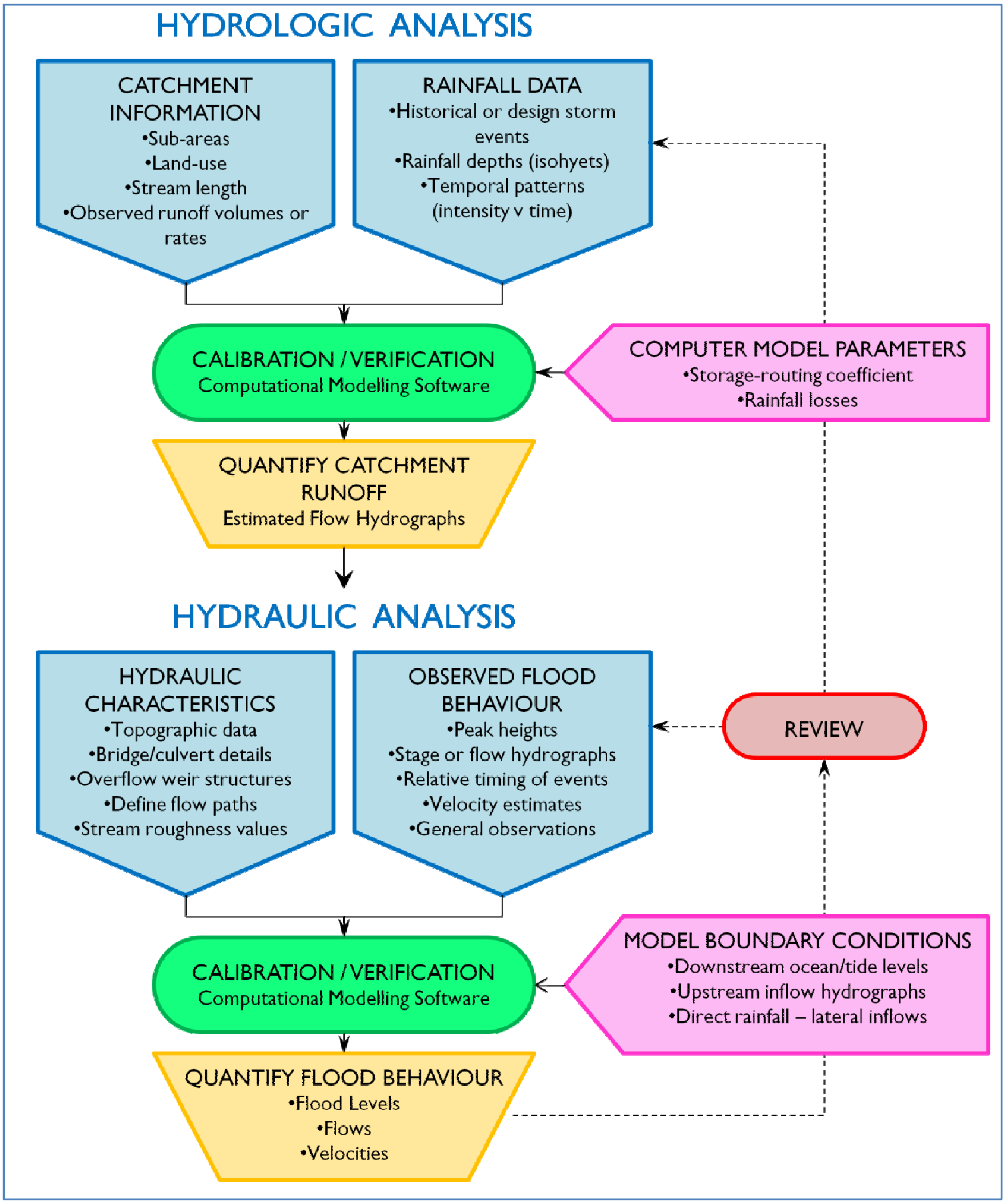
2.6. Downstream Boundary Water Levels

The downstream boundary of the Blackwattle Bay catchment is Blackwattle Bay, while Johnstons Creek catchment discharges to Rozelle Bay. Both bays are tidal, so natural variability of water level is expected in the bay from both tidal and catchment flows. While the water level in both bays affects the flooding behaviour in the lower sections of their respective catchments, the University campuses are sufficiently far upstream such that the tailwater has no influence on the flood levels of the study area. Therefore, a joint probability analysis was not warranted and a tailwater level with an annual recurrence interval of 20 years (1.38 mAHD) was specified at the downstream boundary for both catchments.

3. APPROACH

The approach adopted in flood studies to determine design flood levels largely depends upon the objectives of the study and the quantity and quality of the data (survey, flood, rainfall, flow etc.). In the absence of an extensive historical flood record a flood frequency approach cannot be undertaken for either of the catchments spanned by the University campuses, and must rely on the use of design rainfalls and establishment of a hydrologic/hydraulic modelling system. A diagrammatic representation of the flood study process is shown below.

Diagram 1: Approach Adopted in a Flood Study



4. MODEL BUILD

4.1. Overview

The hydrodynamic modelling program TUFLOW (Reference 5) has been used to model both the hydrologic and hydraulic processes in the two catchments. TUFLOW is a finite difference grid based 1D/2D hydrodynamic model which uses the St Venant equations in order to route flow according to gravity, momentum and roughness. Furthermore, TUFLOW's rainfall on grid functions allows seamless merging of the hydrologic and hydraulic models. This negates the need to use an independent hydrologic model to determine inflow hydrographs for subsequent input to the hydraulic model.

TUFLOW is ideally suited to this study because it facilitates the identification of the potential overland flow paths and flood problem areas as well as inherently representing the available floodplain storage within the 2D model geometry. In addition to this, TUFLOW allows for the utilisation of breaklines at differing resolution to the main grid. Breaklines are used to ensure the correct representation of features which may affect flooding (features such as roads, embankments, kerbs, etc) which is especially important in an urban environment.

The incorporation of 1D elements into the 2D domain is another beneficial factor of TUFLOW. This allows such elements as open channels represented in 1D to function dynamically within the 2D grid. This suits the study as it facilitates the inclusion of channel flow within the context of a medium resolution 2D approach as well as facilitating the inclusion of the pit and pipe network.

For this study, two separate TUFLOW models were used, one for the Johnstons Creek catchment and the other for the Blackwattle Bay catchment. Both models were previously established as part of the flood studies in their respective areas and were refined in the areas representing the University campuses (described further in Section 4.3.7). The model schematisation and results are presented concurrently in this report.

4.2. Hydrology

The hydrologic model boundary covers the entire Blackwattle Bay catchment (315 hectares) and the Johnstons Creek catchment (224 hectares), both shown in Figure 5 (Appendix 1). As the TUFLOW model utilises the direct rainfall method, rainfall for particular events was generated from the IFD data obtained from the BoM (see Section 2.5) and input directly onto the 2D grid of both catchments. To remove spurious losses associated with a DEM's tendency to exaggerate surface depressions (potentially causing a significant portion of rainfall to be retained within the catchment), rainfall is applied only to regions which are likely to collect and distribute flow such as kerbs and gutters. To achieve this, the catchments have been divided into 720 sub-catchments for the Blackwattle Bay catchment and 835 sub-catchments for the Johnstons Creek catchment as shown in Figure 5 (Appendix 1). Each of these subcatchments contains a region to which excess rainfall from the entire sub-catchment is applied.

4.2.1. Loss Parameters

The Australian Rainfall and Runoff 1987 (Reference 3) suggests a range of initial losses are possible (10 to 30+ mm) and a continuing loss of 2.5mm/hr for the pervious regions of catchments within NSW and more specifically Sydney. The conservative lower value of 10 mm initial loss has been adopted for this study. Losses from a paved or impervious area are considered to comprise only an initial loss (an amount sufficient to wet the pavement and fill minor surface depressions) and as such an initial loss of 1.5 mm has been applied with no continuing losses. The same losses were applied in both TUFLOW models, a summary of which is displayed in Table 3.

Table 3: Adopted Design Rainfall Loss Parameters

Parameter	Pervious	Impervious
Initial Loss	10 mm	1.5 mm
Continuing Loss	2.5 mm/hr	0 mm/hr

The above losses are the same as adopted in the nearby Leichhardt Flood Study (Reference 6).

4.2.2. Percentage Impervious

The average perviousness of a catchment plays a significant role in determining the structure of the runoff hydrograph. It has implications for the peak flow, the total runoff volume as well as the time of concentration. Urban regions with large areas of impervious surfaces lose less rainfall to losses and flow reaches the downstream end of the catchment quicker due to the generally smoother surfaces associated with urbanisation[1] (and less initial loss). Thus it is important to determine average imperviousness throughout the catchment for any hydrologic model.

The perviousness of each sub-catchment was not changed from that previously established. The catchment-wide flood studies estimated the imperviousness based on the Local Environmental Plan and assumed a perviousness of 80% for the University campuses. The values for the remainder of the catchments are shown in Table 4. Figure 6 (Appendix 1) provides a land use map for the study area.

[1] Note: A time of concentration of a catchment is also affected by a number of other factors including the catchment slope, shape and size.

Table 4: Percent Imperviousness for Various Land Uses

Land Use Description	% Pervious	% Impervious
Infrastructure (roads, train tracks etc)	10	90
General Residential	30	70
Mixed Use	0	100
Public Recreation (parks, ovals etc)	100	0
University of Sydney	80	20
Light Industrial	0	100
Harold Park	80	20
Local Centre	0	100
Neighbourhood Centre	30	70

4.3. Hydraulic Modelling

In this study, the hydraulic models established convert applied flow (discharge generated by a hydrological model) into flood levels and velocities. In the approach used herein, where the hydraulic model also converts rainfall excess into runoff (i.e. work traditionally carried out by hydrological models), the hydraulic model is the only model run. The hydraulic models for both catchments take an applied rainfall depth (net of losses) and route it to create flood extent, level and velocity information.

More importantly, the TUFLOW model can clearly define 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 integrated easily into a GIS based environment enabling outcomes to be efficiently incorporated into the University's planning activities.

4.3.1. Model Build Process

Model construction begins with the DEM (Digital Elevation Model) which defines a catchment's topographical characteristics at high resolution. Finer features (such as kerbs and gutters) that have significant impacts on flows may then be incorporated via additional spatial layers of information. Also, via the inclusion of dynamically linked 1D elements, drainage pits and pipes are also incorporated. Numerous spatial layers are applied to the model with the aim of closely replicating the catchment's true topographic conditions.

4.3.2. Model Domain and Grid

A two metre 2D grid was generated from the ALS as mentioned in Section 2.2. A computational time step of 0.5 seconds was adopted for the Blackwattle Bay catchment and 0.2 seconds for the Johnstons Creek catchment. Buildings have been excluded from the model as it is assumed that there is very little flow through the structures and minimal temporary floodplain storage.

4.3.3. Roughness Values

The Manning's "n" values for each grid cell were estimated based on established references (e.g. Reference 10) and engineering experience. Values were applied to the 2D overland area based on land use as shown in Table 5. For 1D Manning's roughness values see Section 4.3.4.

Table 5: Adopted Manning's 'n' Values

Land Use	Manning's 'n'
Roads	0.015
Parks	0.06
Parking areas	0.02
Ponds and lakes	0.01
Dense Vegetation	0.08
Residential and mixed use*	0.05

*Buildings were nulled out in the hydraulic model

There is no definitive approach for representing buildings and fences in 2D hydraulic models. The approach to be adopted depends on a number of factors including: the nature of the development; the model extent/grid definition; and the likely impacts of the approach on flood levels and velocities.

For this study it is 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. This was achieved by nulling grid cells based on digitised building outlines which effectively constricted the available flow path.

The "loss" of temporary floodplain storage by nulling the building outlines is a slightly conservative assumption as in reality some floodwaters may enter these buildings under some flooding scenarios. However this approach was adopted as it was considered that the impact of such an assumption would be negligible relative to the overall flood runoff volume.

4.3.4. Pit and Pipe Network

Pit and pipe data (see Section 2.4 for details) provided by Council and the University was used to create a 1D drainage network in TUFLOW. In the greater catchment, pipes of diameter less than 450 mm were excluded from the two models, as it was assumed that they would suffer from blockage during storms. Pipes of less than 450 mm diameter within the University campuses were included to provide more detailed and accurate representation of the local flood behaviour. All pipes and culverts were allocated a Manning's roughness of 0.013 (Reference 10).

4.3.5. Trunk Drainage Blockage

The effect of blockage in urban drainage systems (pipes and open channels) has become a significant factor in design flood estimation following the post flood observations from the North Wollongong August 1998 and Newcastle June 2007 events. However, recent reviews of how blockage should be included in design flood analysis are inconclusive, as it appears that the incidence of blockage is not consistent across all catchments or even within the same catchment. Thus there is no consensus regarding the design approach that should be adopted.

The approach undertaken for the two catchment-wide flood studies was also adopted here. All pipes and culverts have been assumed to have a blockage of 25%. This approach has been adopted to take into account blockage caused by larger debris (such as cars, fencing, vegetation etc.) being swept into drainage structures. All blockages have been assumed to occur at the culvert/pipe level with all pit inlets at 100% capacity.

4.3.6. Boundary Conditions

As the direct rainfall on grid method has been applied to the two models there is no need for upstream flow boundaries. The main boundary condition is at the downstream end of the models at Blackwattle Bay and Rozelle Bay. This is a tidal boundary in which a static tailwater level of 1.38 mAHD (see Section 2.6) has been adopted. This approach has been commonly adopted in similar studies throughout Sydney and is recommended by OEH (Reference 8).

Stage-discharge boundaries were used where overland flows exit the boundary of the catchments. The rating tables for these boundaries were based on an assumption of uniform flow. Their locations are also indicated in Figure 3 (Appendix 1).

4.3.7. Review and Refinement of Existing Models

The previously established TUFLOW models (City of Sydney) that cover both of the University campuses were reviewed and refined to provide a more accurate model representation of the study area where applicable. The refinements include:

- Updating the stormwater drainage network within the campuses;
- Overlaying ground survey points on the existing ALS data at locations where the latter is deemed deficient (e.g. absence of bund at the University Oval No.1);
- Incorporating data describing recent developments on the campuses (listed in Section 2.3), specifically the new building footprints, changes to the surrounding elevations, and changes to the sub-surface drainage;
- Including features like walls that would impede flow paths;
- Modifying sub-catchments delineation where applicable; and
- Verifying overland flow paths.

The data collected is as described in Section 2, and primarily consisted of details pertaining to new developments and the University's stormwater drainage (from a 2002 survey) not present in the existing models. Ground truthing and visual inspection of the University's stormwater drainage were also carried out during a visit to the University campuses in late July 2013 to confirm the validity of the modelling work.

5. DESIGN MODELLING

5.1. Approach

Calibration/verification of the models has been previously undertaken in the catchment-wide flood studies (References 1 and 2) against historical events to ensure their suitability in the modelling of design events, though none of the recorded flood marks were found within the University. Sensitivity analyses have also been conducted as part of these previous studies to assess the effect of changing model parameters on the modelling results.

5.2. Critical Duration

Critical storm duration analysis was undertaken to determine the storm duration that produces the greatest flood levels in the study area for the given design event. A range of storm durations were modelled for the 100 year ARI event and it was found that the critical duration varied (ranging from 15 to 720 minutes) spatially as shown in Figure 7 (Appendix 1). However, the variance in peak flood levels for the tested durations was not considered to be markedly different with all peak flood levels within ±0.1 m. Therefore, for all design events, excluding the PMF, the 2 hour duration was used to determine the peak flood levels.

A similar process was undertaken for the PMF with various PMP durations (1 to 6 hours) modelled so that peak flood levels and associated rainfall durations could be identified. The 1 hour duration PMP was determined to be the critical duration used to determine peak flood levels for the study area within the Blackwattle Bay Catchment and 2 hour duration PMP for the area within the Johnstons Creek Catchment.

5.3. Overview of Results

A number of maps have been produced to display the flood affected regions within the University for the various design events. It should be noted that inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour within the study area. Inundation from local overland flow may vary depending on the actual rainfall event and local influences (parked cars, change in topography, road works etc.).

A summary of the results is provided as follows:

- Peak flood depths and level contours for all design flood events, Figure 8 - Figure 11 (Appendix 1);
- Peak flood velocity for all design flood events, Figure 12 - Figure 15 (Appendix 1);
- Provisional flood hazard categorisation for all design flood events, Figure 16 - Figure 19 (Appendix 1); and
- Preliminary flood hydraulic categorisation for all design flood events, Figure 20 - Figure 23 (Appendix 1).

5.4. Discussion on Flood Risks

The performance of the stormwater drainage system within the study area is governed by the complex interaction between:

- Conveyance within the formal drainage system (pipes and box culverts), and
- Ponding and overland flow along roads and through park lands.

A range of flood depths (see Figure 8 - Figure 11 (Appendix 1)) and velocities (see Figure 12 - Figure 15 (Appendix 1)) can be observed throughout the catchment for the design flood events. One feature of flooding within the study area is that the sub-surface drainage system generally flows at capacity even for smaller events (i.e. 5 year ARI) and the majority of the flows traverse through the University via overland flow paths. Flow velocities are found to be predominantly low throughout the study area except for locations with steep gradients.

A listing of the floor levels and design flood levels of the existing buildings within the University campuses is provided in Appendix B.

5.4.1. Johnstons Creek Catchment

Flood affected area in the University's Camperdown campus (majority of which is located within the Johnstons Creek catchment) include the ovals, sports fields, Physics Building, the Arena Sports Centre, John Woolley Building, Old Teachers' College, the generally low area around Blackburn Building behind the Bruce Williams Pavilion, the University Veterinary Centre and key access roads like Western Ave.

Most of the University's ovals and sports fields act as informal detention basins for flood storage. Flood depths in excess of 1 m can be expected on University Oval No. 1 during the 100 year ARI flood event and close to 1 m on the Hockey Square. For the latter, it poses a major hazard for The Arena Sports Centre with only a 900 mm diameter pipe culvert draining the field as well as conveying flows from the Physics Building upstream and a 450 mm diameter pipe culvert located along the northern edges of the field. Another 900 mm diameter pipe culvert which goes under Western Ave and discharges runoff from St Paul's College and the new Australian Institute of Nanoscience Building site has part of its flow volume diverted to University Oval No. 1 with the provision of a diversion outlet (in the form of a surcharge pit). A previous study (Reference 11) has found that this mitigation measure will alleviate adverse flood impacts downstream whilst elevating the peak flood level within the Oval by less than 10 mm.

Nearby, both buildings (i.e. John Woolley Building and Old Teachers' College) on the corners of the Manning Rd/Western Ave intersection are flood affected as well as the stretch of Western Ave in front of The Arena Sports Centre. A few of the major access roads serve as the overland flow paths for floodwaters to be discharged downstream of the University Campus including Science Rd, Manning Rd, Physics Rd, Western Ave and the Parramatta Rd entrance to the University Veterinary Centre. The cluster of buildings around the Blackburn Circuit near Bruce Williams Pavilion would also be flooded since they are located at a generally low area with limited sub-surface drainage to drain floodwaters during a flood event.

5.4.2. Blackwattle Bay Catchment

Flood affected areas in the University's Darlington campus include the low point on Codrington St in front of the Services Building and the generally low area bounded by Darlington Walk, Shepherd St and Maze Cres.

On Codrington St, a peak flood depth of more than 0.5 m can be expected at the entrance to the Services Building during the 100 year ARI event. This low spot is drained by a 900 mm diameter pipe culvert which goes underneath the building and connects to the local drainage on Lander St. The cluster of buildings bounded by Darlington Walk, Shepherd St and Maze Cres, i.e. Chemical Engineering Building, Civil and Mining Engineering Building, PNR Building and Rose Street Building, are also flood affected in the 100 year ARI event with peak flood depths reaching 0.8 m in the car park area outside of the Chemical Engineering Building. These buildings serve as an obstruction to the flow paths resulting in floodwaters ponding upstream and the area performing as an informal detention basin which retards flows. Therefore, access to these buildings is a major issue during a flood emergency and there is limited space nearby to provide storage of floodwater during a major flood event.

5.4.3. Major Access Road Flooding

Two major arterial roads servicing the University Campus are subject to flooding from events as small as the 5 year ARI event. Parramatta Road and Cleveland Street form one of the main road linkages from the Eastern Suburbs through to the city and into the Western Suburbs. Excessive flooding of these roads could potentially inhibit traffic and result in significant impacts on traffic flows throughout the region. During a significant flood event it is likely that emergency service vehicles would be required in the affected area, though access may be severely hindered by the possibility of major road closures.

5.5. Hazard and Hydraulic Categorisation

The risk to life and potential damages to buildings during floods varies both in time and place across the study area. In order to provide an understanding of the effects of a proposed development on flood behaviour and the effects of flooding on development and people the study area can be sub-divided into hydraulic and hazard categories. This categorisation should not be used for the assessment of development proposals on an isolated basis, rather they should be used for assessing the suitability of future types of land use and development in the formulation of a flood risk management plan for the University Campus.

Hazard is a measure of the overall harm caused by flooding and should consider a number of factors including the depth of flooding, velocity of floodwaters, access to escape routes, duration etc. In the first instance provisional hazard categories can be defined based on the depth and velocity of floodwaters. Provisional flood hazard categories were defined in this study in accordance with the *Floodplain Development Manual - Figure L2* (Reference 7) as indicated in the following.

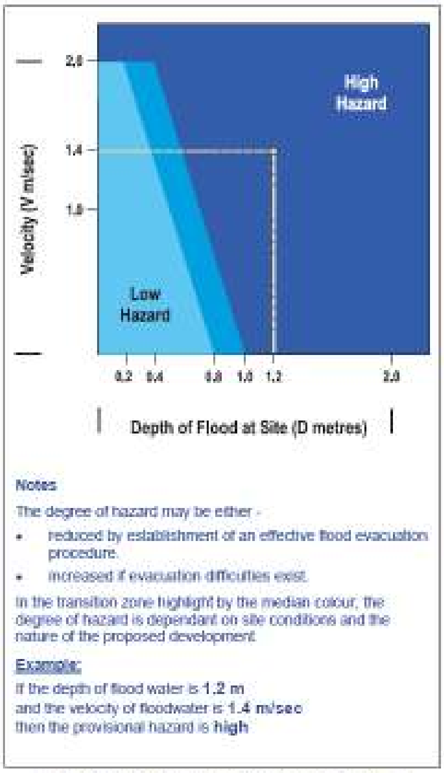


FIGURE L2 - Provisional Hydraulic Hazard Categories

The hazards are provisional because they only consider the hydraulic aspects of flood hazard. High and low provisional hazard areas were defined for all design flood events modelled herein and are provided in Figure 16 through to Figure 19 (Appendix 1). The *Floodplain Development Manual* (Reference 7) requires that other factors be considered in determining the "true" hazard such as size of flood, effective warning time, flood readiness, rate of rise of floodwaters, depth and velocity of floodwaters, duration of flooding, evacuation problems, effective flood access, type of development within the floodplain, complexity of the stream network and the inter-relationship between flows.

From Figure 16 to Figure 19 (Appendix 1), it can be seen that the regions of the study area affected by high hazard flows are those where a combination of high flood depths and velocities occur, with the situation worsening for larger events like the PMF.

Hydraulic categorisation of the study area would be used in the development of a flood risk management plan for the University Campus. The *Floodplain Development Manual* (Reference 7) defines flood prone land to fall into one of the following three hydraulic categories:

- Floodway;
- Flood Storage; and
- Flood Fringe.

Floodways are areas of the floodplain where a significant discharge of water occurs during floods and by definition if blocked would have a significant affect on flood flows, velocities or depths. Areas designated as flood storage are areas of importance for the temporary storage of floodwaters and if filled would significantly increase flood levels due to the loss of flood attenuation. The remainder of the floodplain is defined as flood fringe.

Although the *Floodplain Development Manual* (Reference 7) provides guidelines on determining hydraulic categories it does not explicitly define each category. Consultants and authorities use different approaches for this. For the purpose of this study the preliminary hydraulic categories have been adopted based on previous experience and review of literature (e.g. Reference 9):

- *Floodway = Velocity * Depth > 0.25 m²/s AND Velocity > 0.25 m/s OR Velocity > 1 m/s*
- *Flood Storage = Depth > 0.2 m (provided that NOT categorised as Floodway)*
- *Flood Fringe = Depth < 0.2 m (provided that NOT categorised as Floodway or Storage)*

Figure 20 to Figure 23 (Appendix 1) display the preliminary hydraulic categorisation for all design flood events.

5.6. Key Development Precincts

As part of the CIP, 5 key precincts have been identified for development by the University which are as follows (refer Figure 4 (Appendix 1)):

- Life Sciences Precinct;
- Health Precinct;
- Merewether Precinct;
- City Road Precinct; and
- Engineering Precinct.

These development sites consist of greenfield developments as well as existing buildings for refurbishment or redevelopment. As the University campuses lie within the City of Sydney Local Government Area (LGA), the following planning instruments and controls apply to development within the area:

- Sydney Local Environmental Plan (LEP) 2012; and
- Sydney Development Control Plan (DCP) 2012.

The Sydney LEP 2012 provides overall objectives, zones and core development standards, including the following provisions related to "Flood planning". Clause 7.15 of the Sydney LEP 2012 (Flood Planning) states that:

" a) *The objectives of this clause are as follows:*
   i) *to minimise the flood risk to life and property associated with the use of land,*
   ii) *to allow development on land that is compatible with the land's flood hazard, taking into consideration projected changes as a result of climate change,*
   iii) *to avoid significant adverse impacts on flood behaviour and the environment.*
  b) *This clause applies to land at or below the flood planning level.*

c) *Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:*
   i) *is compatible with the flood hazard of the land, and*
   ii) *is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and*
   iii) *incorporates appropriate measures to manage risk to life from flood, and*
   iv) *is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and*
   v) *is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.*

d) *A word or expression used in this clause has the same meaning as it has in the NSW Government's Floodplain Development Manual published in 2005, unless it is otherwise defined in this clause.*

e) *In this clause:*
   i) ***flood planning level** means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metres freeboard.*"

The Sydney DCP 2012 supports the LEP by providing additional objectives and development standards. Pertinent flood related development controls are summarised for each development precinct in the following sections. The following provisions are provided in the DCP in relation to flood management:

"*Assist in the management of stormwater to minimise flooding and reduce the effects of stormwater pollution on receiving waterways.*"

"*Ensure that development manages and mitigates flood risk, and does not exacerbate the potential for flood damage or hazard to existing development and to the public domain.*"

"*Ensure that development above the flood planning level as defined in the Sydney LEP 2012 will minimise the impact of stormwater and flooding on other developments and the public domain both during the event and after the event.*"

Specific drainage and stormwater management requirements are also provided in the DCP. New developments are required to conform to the flood studies endorsed by Council, which in this case are the Blackwattle Bay Catchment Flood Study (Reference 1) and Johnstons Creek Catchment Flood Study (Reference 2).

Council has also prepared the Draft Interim Floodplain Management Policy to provide direction with respect to how floodplains are managed within the LGA of the City of Sydney. The document provides general requirements for proposed development on flood prone land, Flood Planning Level (FPL) requirements for different development types and guidelines on flood compatible materials.

The following FPL requirements apply for new developments within the University campuses:

Table 6: City of Sydney FPL Requirements

Item	Flood Planning Level
Habitable room floor level: **Inundated by local drainage flooding**	100 year ARI level + 0.5 m or if the flow depth in the 100 year ARI level is <0.25 m then 2 times the flow depth with a minimum of 0.3 m above the surrounding surface
All other habitable properties	0.3 m above surrounding ground
Floor level of a business, schools and child care facilities	Merits approach with a minimum of 100 year ARI level
Above ground car park	100 year ARI level
Below-ground car park	100 year ARI level + 0.5 m or the PMF (whichever is the higher)
Critical facilities including major transport facilities, sewerage and electricity plants etc: **Floor level**	100 year ARI level + 0.5 m or the PMF (whichever is the higher)
Access to and from critical facility within development site	100 year ARI level

A FPL refers to the permissible minimum building floor levels. For below-ground parking or other forms of below-ground development, the FPL refers to the minimum level at each access point. Where more than one FPL is applicable the higher of the applicable FPLs shall prevail.

Based on the requirements outlined in Table 6, Table 7 provides the minimum RL for the proposed development sites (refer Figure 4 (Appendix 1)) majority of which are non-habitable.

Table 7: Minimum RL for Proposed Greenfield and Development Sites (refer Figure 4)

Site	100 year ARI flood level (mAHD)	100 year ARI flood level + 0.5 m (mAHD)	PMF level (mAHD)	Precinct*
G1	26.32	26.82	26.37	Life Sciences
G2	22.79	23.29	23.93	Life Sciences
G3	20.3	20.8	21.61	Life Sciences
G4	21.47	21.97	22.18	Life Sciences
G5	NF	NF	NF	Merewether
D1	23.07	23.57	24.09	Health
D2	26.48	26.98	26.48	Health
D3	NF	NF	41.42	Merewether
D4	NF	NF	NF	Merewether
D5	32.13	32.63	32.15	City Rd
D6	27.75	28.25	29.49	City Rd
D7	27.36	27.86	27.57	City Rd
D8	NF	NF	32.31	Other
D9	22.6	23.1	23.93	Life Sciences
D10	31.02	31.52	31.03	Other
D11	36.92	37.42	37.01	Merewether

NF: Not flooded

*: The Engineering Precinct does not feature here as it only contains refurbishment sites

5.6.1. Life Sciences Precinct

5.6.1.1. Flood Mechanisms

Figure 24 to Figure 26 (Appendix 1) show the peak flood depths and level contours within the Life Sciences development precinct. The flow direction of the floodwaters is indicated by the arrows. It can be seen that floodwaters originating from Science Rd and University Oval No. 2 generally flow in the west direction through the precinct before reaching the trapped depression on Parramatta Road. Flood affectation of the buildings within this precinct is due to local overland flooding.

5.6.1.2. Flood Hazard

Flood hazard around this precinct is generally low for the 100 year ARI event (refer Figure 18 (Appendix 1)) with floodwaters moving at velocity of < 1 m/s towards Parramatta Rd.

5.6.1.3. Flood Risk

Most of the sites zoned for future development are greenfield and developing sites D9 and G2 could potentially lead to obstruction of existing flow paths which will impact on neighbouring lands or buildings. Western Ave and the Veterinary Hospital entrance serve as emergency egress routes for this precinct during a flood event and flows in the surrounding roads are relatively shallow in the 100 year ARI event (< 250 mm). Unlike other development precincts, key facilities within this precinct are mostly found on ground level.

5.6.1.4. Applicable Flood Related Development Controls

As discussed previously, Sydney LEP 2012 and DCP 2012 apply for this development precinct. The flood planning level requirements have been outlined in Table 6 and the relevant levels are provided in Table 7. For new developments, the floor levels for educational facilities and above ground car park should be set above the 100 year ARI peak flood level. Critical facilities like an electricity substation should be placed above the 100 year ARI level + 0.5 m or PMF level, whichever is the higher.

5.6.2. Health Precinct

5.6.2.1. Flood Mechanisms

Figure 27 to Figure 29 (Appendix 1) show the peak flood depths and level contours within the Health development precinct. The flow direction of the floodwaters is indicated by the arrows. Here, floodwaters tend to flow north discharging into University Oval No. 1 which acts as an informal detention basin. Peak flood depths in excess of 1 m can be expected on the Oval during the 100 year ARI flood event. All buildings within this precinct experience flooding above flood level even in frequent events such as the 5 year ARI due to the generally low area where they are located compared to the surrounding terrain.

5.6.2.2. Flood Hazard

Flood hazard around this precinct is generally high for the 100 year ARI event (refer Figure 18 (Appendix 1)) as peak flood depths of up to 1 m are experienced around the main buildings.

5.6.2.3. Flood Risk

The high peak flood depths create a significant flood problem particularly where there is underground storage of expensive equipment or key facilities. Developing site D2 could potentially lead to obstruction of existing flow paths which will impact on neighbouring lands or buildings. In addition, considering the relatively deep overland flows through this precinct, new development must be designed such that the building can withstand forces applied to it by floodwaters (inclusive of debris and buoyancy). Western Ave serves as the only emergency egress route for this precinct during a flood event.

5.6.2.4. Applicable Flood Related Development Controls

Similarly, Sydney LEP 2012 and DCP 2012 apply for this development precinct. The flood planning level requirements have been outlined in Table 6 and the relevant levels are provided in Table 7. For new developments, the floor levels for educational facilities and above ground car park should be set above the 100 year ARI peak flood level. Entry points to underground car park should be at a level above the 100 year ARI level + 0.5 m or PMF level, whichever is the higher. Critical assets should also be placed above the 100 year ARI level + 0.5 m or PMF level, whichever is the higher. If that is not attainable, the entry points to these facilities should be set at least at those levels.

5.6.3. Merewether Precinct

5.6.3.1. Flood Mechanisms

Figure 30 to Figure 32 (Appendix 1) show the peak flood depths and level contours within the Merewether development precinct. The flow direction of the floodwaters is indicated by the arrows. Generally this precinct is relatively flood free and shallow flooding is experienced only on the major roads such as City Rd, Darlington Rd and Codrington St.

5.6.3.2. Flood Hazard

Referring to Figure 18 (Appendix 1), flood hazard within this precinct is generally negligible.

5.6.3.3. Flood Risk

Developments in this precinct should result in minimal flood impact. Due to shallow flooding restricted mainly to the roads, there is negligible flood risk to assets and people for this development precinct.

5.6.3.4. Applicable Flood Related Development Controls

Sydney LEP 2012 and DCP 2012 apply for this development precinct. The flood planning level requirements have been outlined in Table 6 and the relevant levels are provided in Table 7. For new developments, the floor levels for educational facilities and above ground car park should be set above the 100 year ARI peak flood level. Critical facilities like an electricity substation should be placed above the 100 year ARI level + 0.5 m or PMF level, whichever is the higher.

5.6.4. City Road Precinct

5.6.4.1. Flood Mechanisms

The City Road development precinct experiences relatively minimal flooding which is largely caused by overflows encroaching from City Road.

5.6.4.2. Flood Hazard

Referring to Figure 18 (Appendix 1), flood hazard within this precinct is generally negligible.

5.6.4.3. Flood Risk

Developments in this precinct should result in minimal flood impact. Due to shallow flooding restricted mainly to the roads, there is negligible flood risk to assets and people for this development precinct.

5.6.4.4. Applicable Flood Related Development Controls

Similarly, Sydney LEP 2012 and DCP 2012 apply for this development precinct. The flood planning level requirements have been outlined in Table 6 and the relevant levels are provided in Table 7. For new developments, the floor levels for educational facilities and above ground car park should be set above the 100 year ARI peak flood level. Entry points to the buildings from City Road should be raised above the flood planning level. Critical facilities like an electricity substation should be placed above the 100 year ARI level + 0.5 m or PMF level, whichever is the higher.

5.6.5. Engineering Precinct

5.6.5.1. Flood Mechanisms

Figure 33 to Figure 35 (Appendix 1) show the peak flood depths and level contours within the Engineering development precinct. The flow direction of the floodwaters is indicated by the arrows. It can be seen that floodwaters generally flow in the north-east direction through the precinct before reaching the downstream overland flow paths, i.e. Cleveland St, Boundary St and Buckland St. Buildings within this precinct serve as an obstruction to the flow paths resulting in floodwaters ponding upstream and the area performing as an informal detention basin which retards flows. Therefore, the majority of buildings here experience flooding above floor levels.

5.6.5.2. Flood Hazard

Flood hazard around this precinct is generally low for the 100 year ARI event (refer Figure 18 (Appendix 1)) with the exception of a few spots where floodwaters flow at velocity of > 1 m/s. The higher peak flood depths are experienced generally to the south of the Engineering Precinct.

5.6.5.3. Flood Risk

Majority of the existing buildings are found to experience above floor level flooding and this is a significant flood problem particularly where there is underground storage of expensive equipment or key facilities. Considering the relatively deep overland flows through this precinct, new development must be designed such that the building can withstand forces applied to it by floodwaters (inclusive of debris and buoyancy). High velocity flows are experienced on the major access roads including Shepherd St and Cleveland St which are a cause of hazard for people seeking an evacuation route out of the precinct.

5.6.5.4. Applicable Flood Related Development Controls

Sydney LEP 2012 and DCP 2012 apply for this development precinct. The flood planning level requirements have been outlined in Table 6 and the relevant levels are provided in Table 7. For new developments, the floor levels for educational facilities and above ground car park should be set above the 100 year ARI peak flood level. Entry points to underground car park should be at a level above the 100 year ARI level + 0.5 m or PMF level, whichever is the higher. Critical assets should also be placed above the 100 year ARI level + 0.5 m or PMF level, whichever is the higher. If that is not attainable, the entry points to these facilities should be set at least at those levels.

6. MITIGATION MEASURES

6.1. Drainage Capacity Increases

Increasing the flow conveyance capacity of a drainage structure typically involves an increase to the effective flow area of the structure via installation of larger or more pipes/culverts. This generally reduces flood levels upstream of the area where the modifications are made. The resulting increase in flow to downstream areas can cause increases to flood levels and inundation frequency downstream of the modifications, if the increased capacity is not matched throughout the downstream drainage system.

It is generally impractical and uneconomical to design drainage systems that have the capacity to convey flows up to the 100 year ARI magnitude. Urban drainage systems are typically designed to convey the 5 year or 10 year ARI discharge without surcharging or overtopping of the main drainage path. Upgrading the capacity of the existing drainage system in the study area would be a very expensive undertaking considering the University Campus and downstream catchments are already developed.

6.2. Retarding Basins

Retarding basins are small-scale flood mitigation dams commonly used in residential catchments for the purposes of mitigating peak flows by retaining runoff from intense storms and releasing it at a relatively sustained rate. One of the major impediments in their use as a flood mitigation measure for existing development is the lack of suitable sites. For new “greenfield” developments there is the opportunity to incorporate the retarding basins into site design which is not possible for existing development. Retarding basins can also provide water quality benefits, though in a heavily built up urban environment it is difficult to maintain these systems for this purpose.

As several of the University’s ovals and sports fields are already acting as flood storage areas during a flood event, these informal basins could be further enhanced to create additional storage capacity and linked to the existing drainage system in order to provide an effective system for reducing peak flood flows.

6.3. On-Site Detention (OSD)

Generally where retarding basins are used on large developments to restore lost catchment storage, on-site detention is used for the same purpose albeit on individual lots. OSD does not necessarily mean surface water must be attenuated in a basin; storage areas can include flooding above ground to shallow depths over paved areas, such as parking areas, or garden features. Storage can also be provided in underground systems.

OSD devices have been built together with recent developments in the University Campus. Nevertheless, given the location of the University at the upstream part of the catchments, the requirements for these devices are not warranted as long as the proposed developments do not increase peak flows and flood levels downstream beyond the boundaries of the Campus. Furthermore, considering the long term maintenance regime required for these devices to maintain full functionality over time, it may be more feasible to consolidate flood flows at the available informal basins within the University as described in Section 6.2 instead of having OSD systems scattered across the University as required for each new building project.

6.4. Catchment Treatment and WSUD

Catchment treatment is linked with OSD and modifies the runoff characteristics of the catchment to reduce flows. For an urban catchment, this involves planning to maximise the amount of pervious area, maintaining natural channels where practical and the use of Water Sensitive Urban Design (WSUD). These measures can reduce the volumes of stormwater runoff in relatively small, frequent events, typically up to about 5 year ARI events but they have less effect in larger, less frequent events. These measures can be effective on small catchments such as the University Campus but have a negligible impact on large catchments.

As a general concept, catchment treatment techniques and WSUD should be encouraged for example, OSD, limiting on-site imperviousness for developments, controls on land use, along with water quality and other environmental controls as these approaches provide significant benefits to local drainage and overland surface water flooding.

6.5. Levees/Flood Barriers

Levees/flood barriers are a means of excluding floodwaters from areas that would otherwise be inundated. Both measures can prevent inundation up to a designated design level (with a freeboard allowance of typically 0.5 m) and have been widely used for this purpose. Levee banks are generally made of compacted earth and can usually be successfully landscaped to produce minimal visual impact. Flood barriers can be in the form of a vertical flood wall constructed from pre-fabricated concrete elements.

There are currently no formal levees protecting existing buildings in the study area though flood walls could be constructed surrounding sensitive locations like Physics Building and Madsen Building where expensive laboratory equipment is located below ground level.

6.6. Temporary Flood Barriers

Temporary flood barriers include demountable defences, wall systems and sandbagging which are deployed before the onset of flooding. For the study area, sandbagging is a more appropriate solution for dealing with flooding in smaller areas and at individual buildings. However, this relies on warning time and availability of sandbags and people to place them. Although sandbagging can be used to prevent ingress of floodwaters into a building or access area it is not recommended as the primary risk management solution. Sandbagging should only be used in instances where additional temporary flood protection is required and should only be deployed when safe to do so.

7. CONCLUSIONS

A Campus Flood Study Review, as reported upon herein, has been undertaken for the University of Sydney Camperdown and Darlington campuses. Flooding mechanism for this study area is primarily local overland flow (runoff in excess of pit/pipe drainage systems). This study has defined existing flood behaviour for a range of floods from the 5 year ARI to the Probable Maximum Flood event and the results are presented herein.

The work carried out for this study has been verified by a limited calibration exercise to historical data as part of the catchment-wide flood studies for Blackwattle Bay Catchment and Johnstons Creek Catchment. It is based on best practice and produces inundation results which are in line with previous investigations and expectations.

Flood liability within the study area is a result of extensive development (filling of the floodplain and blocking of flow paths) in conjunction with pervious surfaces converted to impervious surfaces. The restricted overland flow paths running south to north through the University Campus exacerbate the flood liability of the area. In addition the minor and major drainage systems are of limited capacity.

Through this study a number of flood prone areas were identified which include the low point on Codrington St in front of the Services Building and the generally low area bounded by Darlington Walk, Shepherd St and Maze Cres in the University's Darlington campus. In the University's Camperdown campus (majority of which is located within the Johnstons Creek catchment) the flood affected areas include the ovals, sport fields, Physics Building, the Arena Sports Centre, John Woolley Building, Old Teachers' College, the generally low area around Blackburn Building behind the Bruce Williams Pavilion, the University Veterinary Centre and key access roads like Western Ave.

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Figures

FIGURE 1
LOCALITY MAP

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FIGURE 2
EXISTING TOPOGRAPHY
UNIVERSITY OF SYDNEY

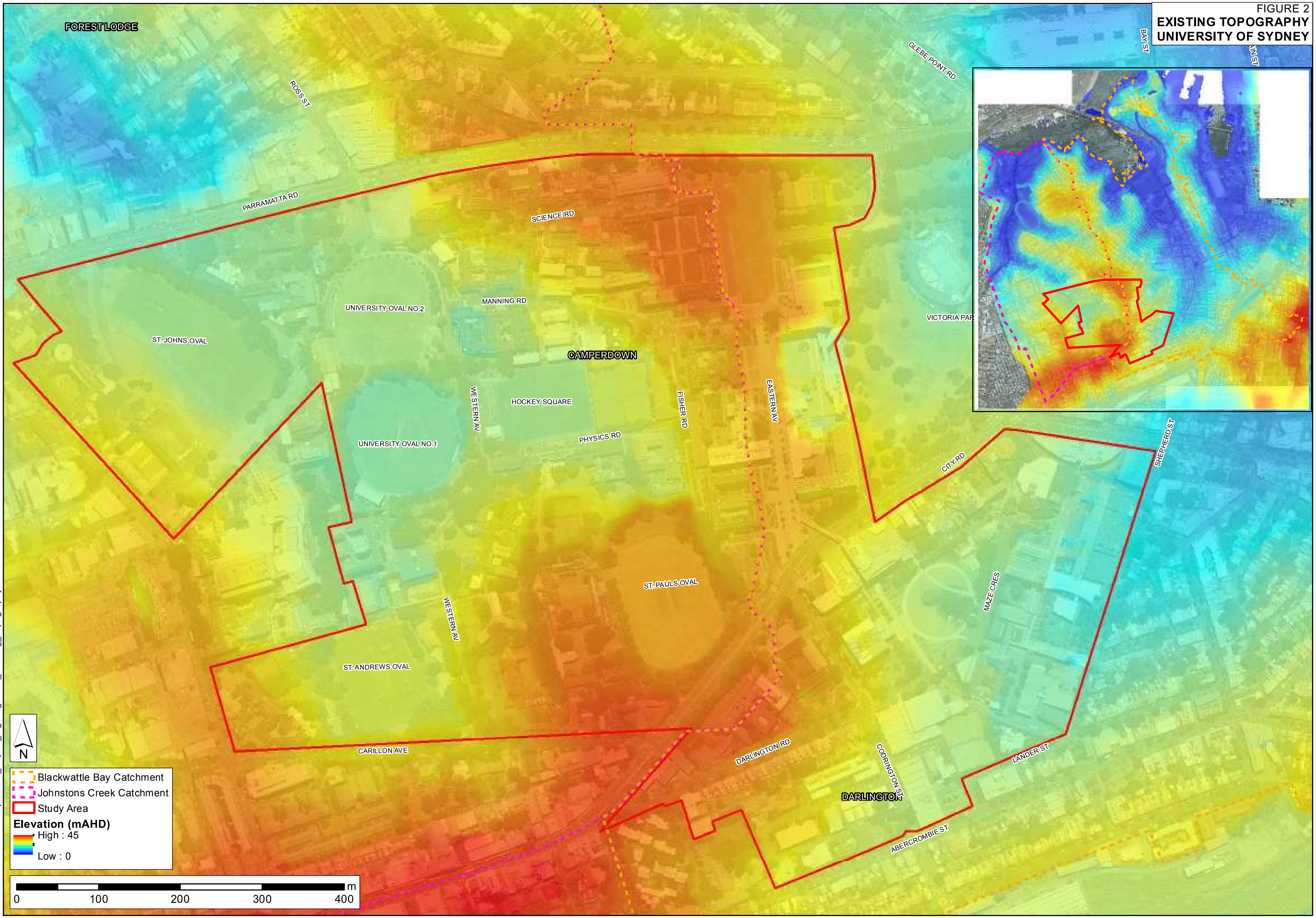

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FIGURE 3
DRAINAGE SYSTEM & HYDRAULIC MODEL LAYOUT
UNIVERSITY OF SYDNEY

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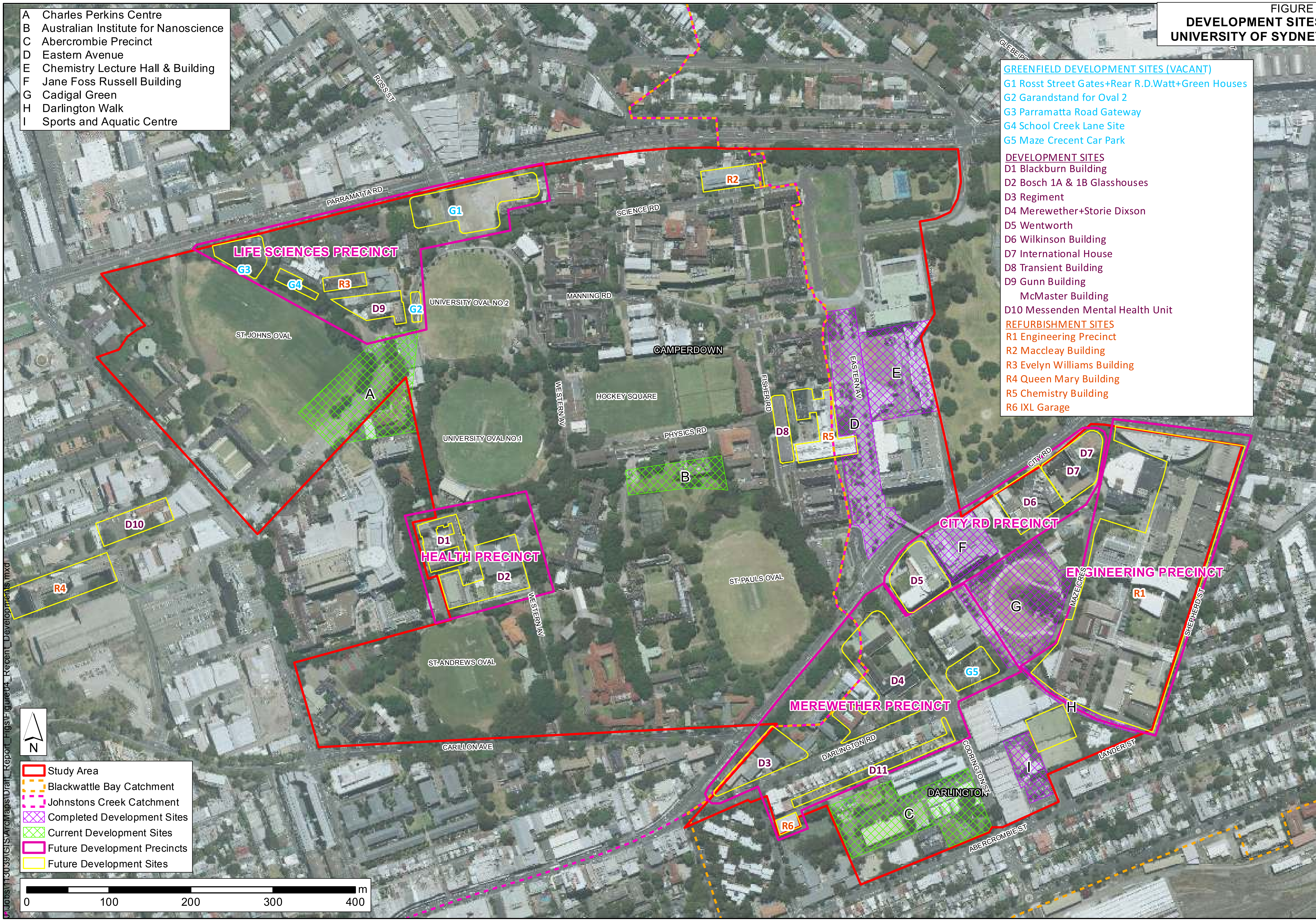

FIGURE 4
DEVELOPMENT SITES
UNIVERSITY OF SYDNEY

FIGURE 5
HYDROLOGICAL SUBCATCHMENTS
UNIVERSITY OF SYDNEY

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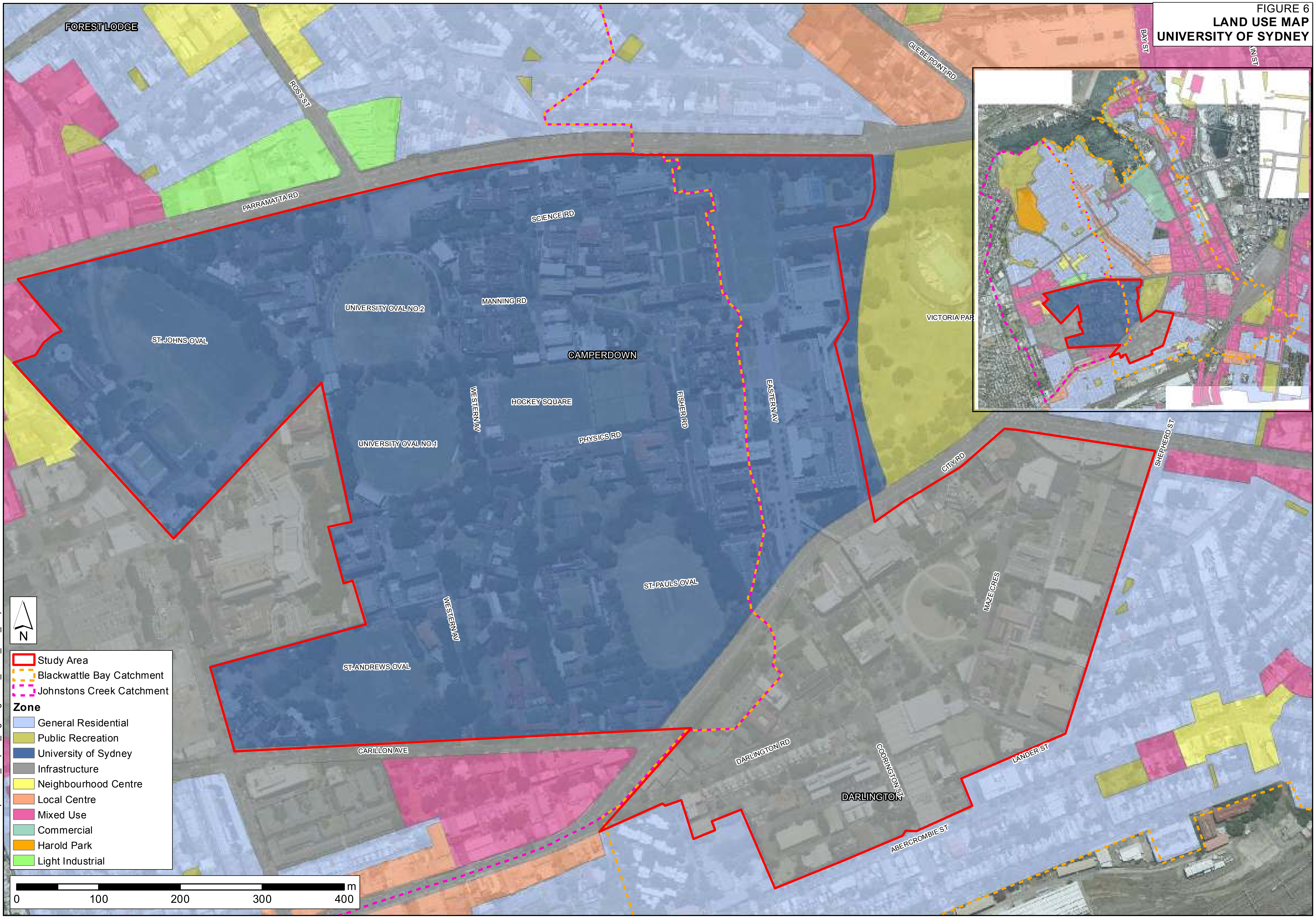

FIGURE 6
LAND USE MAP
UNIVERSITY OF SYDNEY

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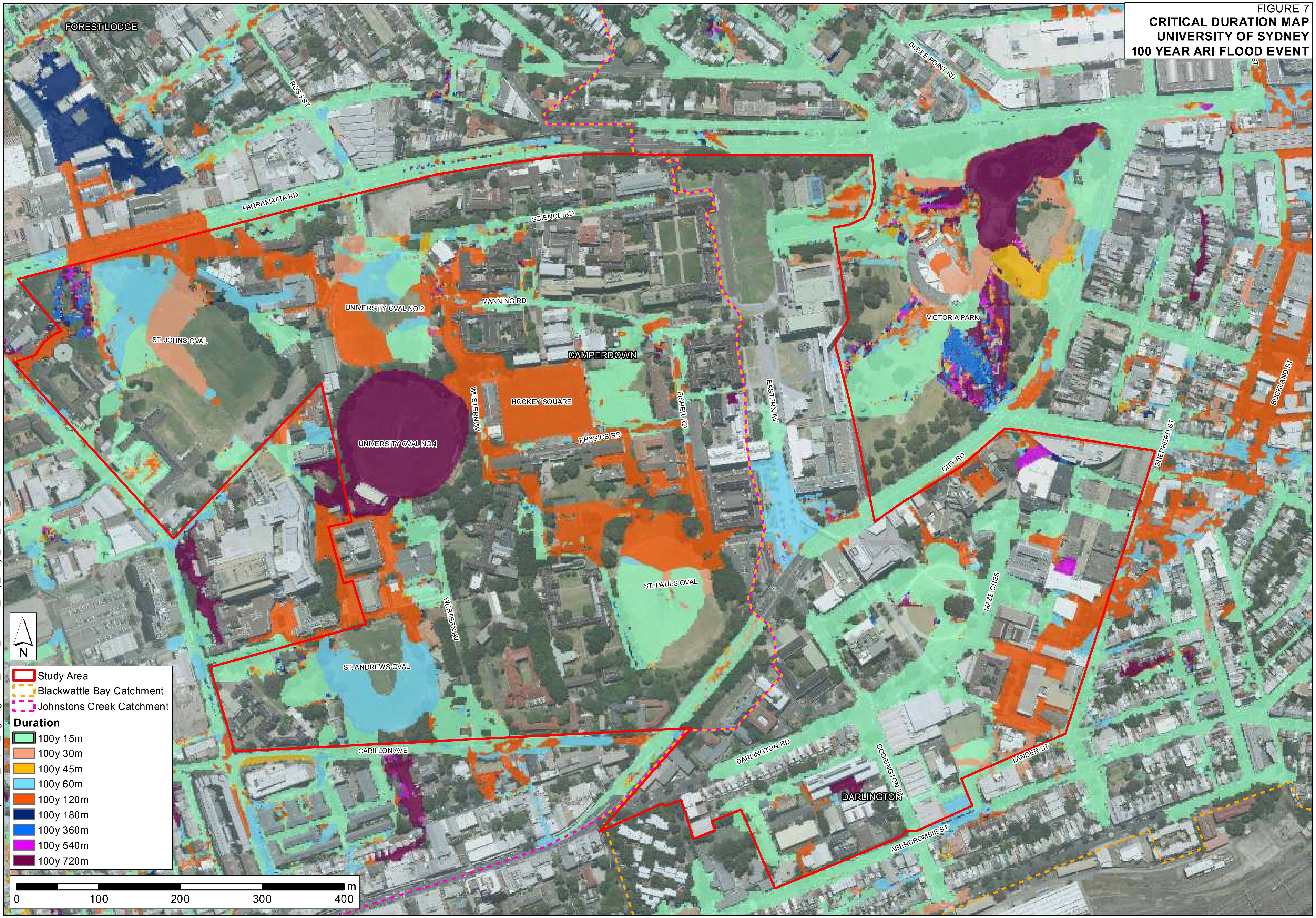
FIGURE 7
CRITICAL DURATION MAP
UNIVERSITY OF SYDNEY
100 YEAR ARI FLOOD EVENT



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